AMERICAN COLLEGE OF OCCUPATIONAL AND ENVIRONMENTAL MEDICINE

Traumatic Brain Injury

Effective June 26, 2025

TABLE OF CONTENTS

SUMMARY OF RECOMMENDATIONS

Effective June 26, 2025

The Evidence-based Practice Panel's recommendations are based on critically appraised higher-quality research evidence and on expert consensus observing First Principles when higher-quality evidence is unavailable or inconsistent (see Methodology). The reader is cautioned to utilize the more detailed indications, specific appropriate diagnoses, temporal sequencing, preceding testing, and noninvasive treatment options that are elaborated in more detail for each test or treatment in this guideline when using these recommendations in clinical practice or medical management. These recommendations are not simple "yes/no" criteria.

All ACOEM guidelines include analyses of numerous interventions, whether or not FDA-approved. For non-FDA-approved interventions, recommendations are based on the available evidence; however, this is not an endorsement of their use.

Recommendations are made under the following categories:

- Strongly Recommended, "A" Level
- Moderately Recommended, "B" Level
- Recommended, "C" Level
- Insufficient-Recommended (Consensus-based), "I" Level
- Insufficient-No Recommendation (Consensus-based), "I" Level
- Insufficient-Not Recommended (Consensus-based), "I" Level
- Not Recommended, "C" Level
- Moderately Not Recommended, "B" Level
- Strongly Not Recommended, "A" Level

WORKFLOWS

- Algorithm 1. Acute Traumatic Brain Injury
- Algorithm 2. Severe Traumatic Brain Injury
- Algorithm 3. Rehabilitation Assessment and Treatment

INTRODUCTION

This clinical practice guideline presents evidence-based recommendations for assessing and treating adults with traumatic brain injury (TBI). Topics include the initial assessment and diagnosis of patients with TBI, identification of red flags that may suggest the presence of a serious underlying medical condition, initial clinical evaluation, management, diagnostic considerations and special studies to identify clinical pathology, work-relatedness, modified duty and activity, rehabilitative strategies, and return to work, as well as further management considerations including delayed recovery.

Guidance is provided on the treatment of working-age adults who have sustained TBI, as well as the evaluation and management of symptoms ranging from acute/subacute to chronic. The primary target users of this guideline are clinicians. Although the primary

patient population is working adults, the principles may apply more comprehensively. This guideline does not address several broad categories, including the impact of cerebrovascular accidents, concomitant congenital disorders, or malignancies. It also does not address specific intraoperative procedures.

The objectives of this TBI guideline include baseline evaluations, diagnostic tests and imaging, physical activity, return to work, medications, physical and occupational therapy, injections, and rehabilitation. Comparative effectiveness is addressed where available. This guideline does not address comprehensive psychological and behavioral aspects of pain management; these are addressed separately in the ACOEM Chronic Pain guideline. Cervical spine pain and related disorders are addressed in the ACOEM Cervical and Thoracic Spine Disorders guideline.

The health questions for acute, subacute, chronic, and postoperative TBI disorders addressed by this guideline include the following:

- What evidence supports the initial assessment and diagnostic approach?
- What red flags signify serious underlying condition(s)?
- What diagnostic approaches and special studies identify clinical pathology?
- What initial treatment approaches have evidence of efficacy?
- What is the evidence of work-relatedness for various diagnoses?
- What modified duty and activity prescriptions and limitations are effective and recommended?
- When is return-to-work status recommended?
- When initial treatment options fail, what evidence supports other interventions?
- When and for what conditions are injections and other invasive procedures recommended?
- What management options are recommended for delayed recovery?

A detailed list of search questions in a PICOT-type format (Patient/Population, Intervention, Comparison, Outcome, Time) is provided in Appendix 1.

A detailed methodology document used for guideline development is available online as a full-length document and has also been summarized elsewhere [(1)]; the methodology document includes evidence selection, scoring, incorporation of cost considerations [(2, 3)], and formulation of recommendations. All evidence garnered from seven databases (Medline, EBM Online, Cochrane, TRIP, CINAHL, EMBASE, PEDro) was included in this guideline. Comprehensive searches for evidence were performed with both PubMed and Google Scholar up through 2024 to help assure complete capture and included prior systematic reviews for this guideline. There was no limit on year of publication. Search terms are listed with each table of evidence. Guidance was developed with sufficient detail to facilitate the assessment of compliance [(2)] and auditing/monitoring [(3)]. Alternative options to manage conditions are provided. It is recognized that there are differences in workers' compensation systems [(4)]. There also are regional differences in treatment approaches [(5, 6, 7)]. Furthermore, distance to services has been identified as a key variable that adversely affects patients [(8)]. Also relevant for TBI, American Indian/Alaskan natives have the highest incidence rates of TBI deaths and Black/African-Americans are most likely to sustain TBI from violence [(9)].

This guideline has undergone extensive external peer review. All AGREE II [3, 10], IOM [2], AMSTAR, and GRADE criteria are adhered to. In accordance with the IOM's Trustworthy Guidelines, detailed records are kept, including responses to external peer reviewers [2].

The Evidence-based Practice Traumatic Brain Injury Panel and the Research Team have editorial independence from the American College of Occupational and Environmental Medicine (ACOEM) and MDGuidelines, which have not influenced the guidelines.

IMPACT

The global incidence of traumatic brain injury (TBI) has been estimated at 69 million people annually [11]. There were 214,110 TBI-related hospitalizations in the US in 2020 and 69,473 TBI-related deaths in 2021 [12, 13]. The crude incidence rate of TBI is much more difficult to measure because the overwhelming majority of cases are mild TBI/concussion cases (estimated at 95% [14]) and are treated as outpatients, if they are evaluated and treated at all; therefore, there is a wide range of estimates in epidemiological studies. A meta-analysis estimated the global annual incidence rate at 295 per 100,000 [15]. The adjusted risk among males is uniformly higher, and the rate among US males is 3.3-fold greater [16].

It is believed that factors such as automobile safety, seat belt use, helmet use, and better overall treatment for severe TBI in prehospital and hospital settings (with a focus on avoiding hypoxia, hypotension, and hyperventilation), while unable to prevent TBI entirely, have somewhat mitigated the impacts and severity of TBI and thus mortality. Yet, prospective cohort data also indicate an additional challenge in that the mortality risk is 81% elevated over a 14-year period after sustaining a TBI, although it did not distinguish between mild, moderate, and severe TBI [17].

A systematic review estimated that 17.9% of TBI cases were work-related, 76% occurred in males, the mean age was 40.4 years, and 3.6% resulted in death [18]. A population-based study of worker's compensation claims in Ohio found a rate of 51/100,000 FTEs; 40% had lost work time and the highest rates were among spectator sports and general freight trucking [19]. A Korean study of workers compensation insurance data reported a work-related TBI incidence rate of 28.4/100,000, of which the mild rate was 12.9/100,000 and 15.5/100,000 were moderate to severe; construction was the most common industry (39.7%), followed by 19.7% from manufacturing; 86.4% had lost work time; 91.2% sustained an inpatient hospital stay; the median duration of work disability was 148 days; and the mean total claim cost was $45,082 [20]. A Montreal trauma center-based study indicated most work-related TBI cases occurred in construction industry, the most common mechanism of injury was a fall, and 76.8% were mild TBI cases [21]. Another systematic review found falls to be the most common mechanism of injury [22].

A U.S. naval health study reported a cumulative prevalence rate for service-related TBI of 27%, with the highest risk among those serving in "Infantry, Gun Crews, Seamanship" (OR=1.79, 95% CI 1.58-2.02) [23, 24]. Military causes of TBI have been associated with long-term risk of job loss after separation from service [25]. For TBI among military personnel, disability estimates vary strongly by severity: 12.0% among those with mild TBI, 31.4% for those with moderate TBI, 56.2% for penetrating TBI, and 65.6% for severe TBI [26]. The civilian data likely underestimate the prevalence of TBI because they do not include persons with TBI sequelae who were treated and released from emergency departments, those who sought care in other healthcare settings, and those who did not seek treatment [27, 28].

A California database study found that 11.2% of mild TBI claims were due to workplace violence [29]. Although TBI may occur less frequently in the workplace compared to other injuries, the unique needs of workers who sustained TBI has been noted to include the need to focus on functional restoration and return to work.

TBI also carries enormous per-capita costs, in large part due to vocational issues of impairments, employability, and productivity. Annual healthcare costs for all U.S. TBIs have been estimated at $40.6 billion [30]; however, those cost estimates do not include what are likely substantially greater total costs, including disability, impairments, work lost time, and reductions in productivity. An estimated 5 million Americans are living with disability from TBI [31]. Between 3.2 and 5.3 million persons (1.1%-1.7% of the U.S. population) live with long-term disabilities that result from TBI [32].

DEFINITIONS AND RELATED TERMS

Active Therapy: The term "active therapy" is generally thought of as the patient taking an active role in their treatment via various modalities. Although there is not one specific treatment defined by this term, it may include psychological, social, and educational components in conjunction with therapeutic exercises [33]. Therapeutic exercises could include light aerobic activity, directional exercises, muscle reconditioning (light weight-lifting or resistance training), physiotherapy, graded exercise stress training and active physical or occupational therapy [34].

Acute, Subacute, and Chronic: In the ACOEM guidelines, *acute* is defined as a duration of less than 1 month. *Subacute* is defined as a duration of 1 to 3 months. *Chronic* is a duration of greater than 3 months.

Anoxic Brain Injury: This is a consequence of any insult to the brain resulting from insufficient oxygen supply to the brain. Causes include cardiovascular, pulmonary, environmental (e.g., low-oxygen atmospheres, low-pressure atmospheres, drowning), toxins (e.g., carbon monoxide, cyanide), and trauma to carotid or vertebral arteries and/or to the brain proper.

Chronic Traumatic Encephalopathy: Chronic traumatic encephalopathy (CTE, with its clinical condition of traumatic encephalopathy syndrome) is hypothesized to be a neurodegenerative disorder with perivascular deposition of hyperphosphorylated tau (p-tau) as neurofibrillary tangles, which is distinct from aging and Alzheimer disease [35, 36]. However, this theory is not without controversy and quality data supporting it are sparse [37-39]. Systematic reviews and meta-analyses using different inclusion criteria and analytic approaches have found supportive evidence [40-42], as well as a lack of statistically significant supportive evidence [43].

This disease is hypothesized to result from exposure to multiple TBI injuries over time and has been diagnosed particularly in elite athletes and combat military personnel [36, 44, 45], with symptoms of irritability, impulsivity, aggression, depression, short-term memory loss, cognitive changes, and purportedly heightened suicidality [46]. The theory includes that there is potential for the development of advancing disease and more severe neurological changes, including dementia, gait and speech abnormalities, and Parkinsonism [47]. The late stages of the disease have been theorized to be similar to Alzheimer disease regarding frontotemporal dementia [48]. Some reports suggest that CTE may be distinguished by generalized atrophy of the cerebral cortex, medial temporal lobe, diencephalon and

mammillary bodies with enlarged ventricles; cavum septum pellucideum, often with fenestrations and extensive p-tau immunoreactive neurofibrillary tangles, and astrocytic tangles in frontal and temporal cortices. It has been reported that CTE may be distinguished from Alzheimer disease by having a significant burden of p-tau tangles in the hippocampus [36], although this is not yet a clearly established fact [49]. The overall body of epidemiological studies supporting a relationship between TBIs and CTE may be characterized as low quality [50].

Concussion: Concussion has been variously defined [51, 52]. In general medicine and in much of the quality research literature, "concussion" and mild traumatic brain injury (mTBI) have been and continue to be used as equivalent terms [53, 54]. For purposes of this guideline, concussion is defined as a transient alteration in neuronal function and in cerebral blood flow caused by a blow to the head, neck, and/or body with transmission of force to the head, brain, and/or brainstem, which leads to immediate or modestly delayed neurological symptoms [55]. In keeping with the U. S. Department of Veterans Affairs (VA) and Department of Defense (DoD) guideline [56], this ACOEM guideline categorizes cases with abnormal imaging findings as moderate/severe. Because of the variability in definitions of "concussion" and "mTBI" found in the literature, a more precise diagnosis based on the mechanism of injury and its effects is recommended.

Delayed Recovery: Delayed recovery is an increase in the period of time prior to returning to work or usual activities compared with the length of time expected based on average expectations, severity of the disorder, and treatments provided.

Dementia: Dementia has been theorized to occur as a more severe outcome of chronic traumatic encephalopathy (see above). Regardless of the mechanism, many studies have reported increased risk of dementia in those sustaining TBI [36, 57-64]. Often the diagnosis of mild cognitive impairment (MCI) is a predecessor of dementia [65, 66]. The risk of dementia has been estimated as a 2.3-fold increased risk after moderate brain injury and 4.5-fold increased risk after severe head injury [58]. TBI in older veterans has been associated with a 60% increased risk of developing dementia [67]. Evidence after mild TBI is less strong [68, 69], with a meta-analysis calculating a risk of 1.96-fold [64].

Functional Capacity Evaluation: A functional capacity evaluation (FCE) is a comprehensive battery of performance-based tests to attempt to determine an individual's ability to do work-like tasks and conduct activities of daily living [70]. An FCE may be done to identify an individual's willingness/ability to perform specific tasks associated with a job (job-specific FCE) or their willingness/ability to perform physical activities associated with any job (general FCE). The term "capacity" used in FCE is problematic, as an FCE generally measures performance tolerance (current demonstrated ability) and effort, rather than capacity, and may thus at times, be misleading. Further, published literature suggests the predictive or future performance is relatively weak (see FCEs). FCEs may be utilized for medical-legal purposes to attempt to address residual physical tolerances and potential for rehabilitation in preparation for judicial determination of loss of earning capacity.

Functional Improvement *(especially Objective Evidence):* Evaluation of the patient prior to the initiation of treatment should include documentation regarding objective physical findings (e.g., range of motion, reflexes, strength), pain level (if any), and current functional abilities both at home and at work. This should include a clear statement regarding what objective or functional goals are to be achieved through the use of the treatment. These

measures should be tracked during treatment and evidence of progress towards meeting these functional goals should be sought. Examples of documentation supporting improved function would be increased physical capabilities (with focus on job-specific activities), reduction in workplace or avocational limitations, and through tools such as ANAM, SCAT [71, 72], and MACE [72, 73]. Headache is frequent after trauma to the head or neck (Theeler et al., 2009) and can be assessed using the MIDAS. (If there are spinal pain issues or functional compromise, usable tools may include the PROMIS [74], Neck Disability Index [75-82], Bournemouth Neck Disability Questionnaire [83], Modified Oswestry Questionnaire [84, 85], Patient Specific Functional Scale, and Roland-Morris Disability Questionnaire [86, 87]. Resolution of physical findings (such as cognitive function, increased muscle tone, radicular symptoms, or weakness) or increased range of motion, strength, or aerobic capacity may be physical examination correlates of improved function.

Functional Restoration: Functional restoration, like active therapy, is not one specific set of exercises, processes, or therapies, but a blend of various techniques and programs (both physical and psychosocial). The basic principle for all of these individually tailored programs is to help patients cope with pain and return to the functioning level required for their daily needs and work activities [88]. Functional restoration refers to a full-day multidisciplinary program lasting from 3 to 6 weeks [89]. There also include work conditioning and work hardening programs that are utilized [90, 91] (see the ACOEM Chronic Pain guideline for further discussion).

Glasgow Coma Scale (GCS): The Glasgow Coma Scale is a neurological scale that provides a measure of the conscious state of a person that was designed to assess the patient's initial TBI presentation [92]. While GCS has been used to attempt to subsequently assess the patient and track recovery, there are other scales that are better designed for those purposes. The GCS is scored between 3 and 15, with 3 being the worst score and 15 the best (3-8=severe; 9-12=moderate; 13-15 mild; 13-15 with positive acute neuroimaging findings is considered mild complicated). It is composed of three parameters: Best Eye Response, Best Verbal Response and Best Motor Response. See Table 1 for details.

Glasgow Outcome Scale-Extended (GOSE): The Glasgow Outcome Scale-Extended is a scale developed to attempt to standardize the measurement of TBI outcomes [93, 94]. The GOSE emphasizes assessment of global function through patient (or surrogate) interview. It categorizes the postinjury level of disability and quality of life by evaluating the ability to perform activities of daily living, work, social participation, and relationship management. GOSE may be used to track TBI recovery.

Myofascial Pain: Proponents believe that pain arising from muscles and fascia can be recognized as distinct from pain arising from ligaments, joints, and discs. However, there is no valid way to determine whether the source of neck or thoracic pain is or is not from muscles or fascial structures. Even though some authors have published on “myofascial neck pain, " in this review myofascial pain is considered as non-specific cervical or thoracic pain (see the Shoulder Disorders guideline for myofascial pain and trigger points).

Neck Disability Index: The Neck Disability Index is a revised form of the Oswestry Low Back Pain Index for the assessment of activities of daily living of cervical pain patients, particularly from whiplash type injuries [75-80, 82]. It contains 10 sections addressing the impact of the cervical pain including – pain intensity, personal care, lifting, reading, headaches,

concentration, work, driving, sleeping, and recreation [75]. However, the tool is not standardized and is frequently modified, making interpretations problematic [95].

Neck Pathology and Occipital Neuralgia: Occipital neuralgia, also known as C2 neuralgia (or neuralgia of the second cervical nerve), is pain in the greater and/or lesser occipital nerves. Posterior head and neck pain may also occur with involvement of other nerve roots, e.g., C3 and C4. There are many potential causes of the condition, which is due to mechanisms including nerve entrapment, irritation, and/or nerve trauma [96]. Compression or irritation of the nerve structures may cause pain in the posterior head and neck. Traumatic mechanisms often involve pain thought to originate in the atlantoaxial or upper zygapophyseal joints or in the muscles and insertion areas [97, 98].

Occupational Therapy: Occupational therapy typically involves a collaborative, client-centered approach that emphasizes engaging an individual in "occupations" and/or everyday activities to maximize functional independence. Contexts and environments may include activities of daily living (ADLs), work, play, education, social participation, rest/sleep, and leisure.

Outcome Predictors (Cognitive OP, Psychological OP, Vocational OP): Outcome predictors are measured variables used to estimate the impacts of a specific injury. They usually include tests and batteries of tests. They may include clinical signs, although various cognitive function tests are prominent examples of outcomes predictors used for TBIs. They may be used both for baseline assessments, prognostic assessments, as well as to track clinical progress. TBIs are a heterogeneous group of injuries that have a wide range of possible effects potentially including impairments in learning, memory, speech and communication, walking and balance, concentration, attention, problem-solving, and decision-making, all of which may be acute, subacute, and/or chronic [99-102]. Therefore, there is a similarly wide array of potentially useful outcome predictors for these types of TBIs. Current predictors for TBI include the Glasgow Outcome Scale, ImPACT, MACE, SCAT, King-Devick, Sport Concussion Assessment Tool-6, imaging tests (e.g., CT scans, functional MRI, DTI, and PET-CT scans), gender, and cognitive tests [103, 104].

Among the higher cortical function prognostic tests, these predictors may be broken down further into three separate groups: *cognitive, psychological,* and *vocational*. Cognitive outcome predictors are used to estimate abilities to learn about information and understand it. Examples that may be used include formal neurocognitive screens or other assessments, measuring S100B, GFAP, and UCL-L1 [105] as potential biomarkers of TBI. The window of utility for such assays can encompass 12-36 hours post-injury. Outcome measures of injury severity include loss of consciousness (LOC), posttraumatic amnesia (PTA) and headache [106-108]. Psychological outcome predictors are used to foresee possible behavioral changes and mental and emotional instability within a patient post-injury. Examples of these predictors are injury severity and the Hospital Anxiety and Depression Scale (HADS) [109, 110]. Many psychological predictor outcomes have less supportive evidence of their utility. Regardless, these include emotional expression recognition, understanding of others' mental state, and cognitive fluency or flexibility [111, 112]. Vocational outcome predictors are used to estimate a patient's ability to return to work and working performance. A few of these predictors include age, pre-morbid educational status, pre-morbid psychological disorders, employment status at time of injury, primary payer, injury severity, length of stay, motivation, accurate self-awareness, and full acceptance of returning to work [109, 113, 114].

Passive Modality: Passive modalities refer to various types of treatment given by a clinician that usually involve administration of some form of stimulus being applied to the body as opposed to the individual actively doing some sort of therapy (see Active Therapy). Forms of passive modality include massage, hydrotherapy (e.g., whirlpools, hot tubs, spas), ultrasound, and hot/cold compresses.

Parkinson Disease (and Parkinson Pugilistica): Parkinson disease (PD) is the second most common neurogenerative disorder next to Alzheimer disease, with an incidence rate of approximately 13.4 per 100,000 per year. The cause is most commonly idiopathic, but may include genetic and environmental factors. Parkinson disease is theorized to occur with increased incidence in cases of chronic traumatic encephalopathy, sometimes termed *Parkinson pugilistica* [115-118].

Physical Therapy: Physical therapy (PT) is a profession that uses numerous treatments or modalities to effect superior clinical outcomes, often including aerobic exercises, conditioning exercises, and various modalities. The ACOEM guidelines develop guidance for specific treatments rather than undefined or vague treatments by a profession (e.g., PT treatment or "medicine treatment"). However, it is important to note that much of the available research uses PT and "exercises" generically. Furthermore, rehabilitative therapy may be performed by or under the direction of trained and licensed individuals such as physical therapists, occupational therapists, exercise physiologists, chiropractors, athletic trainers, and physicians. Jurisdictions may differ on the qualifications for licensure to perform these interventions. The ACOEM guidelines are not meant to restrict physical therapy to being performed only by physical therapists.

Ranchos Los Amigos Scale: The Rancho Los Amigos Scale is used to measure cognition and behavior in patients with TBI [119]. The scale may be used to track recovery from the injury.

Traumatic Brain Injury (TBI): TBI is a nondegenerative, noncongenital insult to the brain, neck or body transmitted to the head from an external mechanical force, possibly leading to temporary or permanent impairment of cognitive, physical, and psychosocial functions, with an associated diminished or altered state of consciousness [120-122]. A consensus definition [121] of TBI is “an alteration in brain function, or other evidence of brain pathology, caused by an external force. ”

The most common, historic classification of TBI severity is based on presence or absence of consciousness, length of loss of consciousness (if present), presence and duration of posttraumatic amnesia, and structural imaging findings. The Glasgow Coma Score is included in some, but not other classifications of TBI; its inclusion is not without controversy, as the Glasgow Coma Score was originally intended for critical care triage and is a imprecise instrument when used as a prognostic tool; clinical courses and outcomes can readily cross these categories [123]. However, this has a tenuous relationship with duration of symptoms and need of treatment (e.g., some individuals with mild impairment have ongoing symptoms while some sustaining moderate have rapid, full recovery). As this guideline is based on quality evidence and most studies have used the traditional severity classification system, it is advised that caution be used to emphasize treatment of the patient’s symptoms and not rigidly apply the traditional severity system.

For purposes of classification, this guideline adopts the American College of Rehabilitation Medicine classifications [55] with one exception. That exception is that mild TBI does not include evidence of intracranial bleeding. Mild TBI is defined as involving a plausible

mechanism of injury from an external force inducing a physiological disruption of brain function. Mechanism(s) of Injury involve a transfer of mechanical energy to the brain from external forces resulting from the: (1) head being struck with an object; (2) head striking a hard object or surface; (3) brain undergoing an acceleration/deceleration movement without direct contact between the head and an object or surface; and/or (4) forces generated from a blast or explosion. ACRM also noted that the diagnostic label 'concussion' may be used interchangeably with 'mild TBI' when neuroimaging is normal or not clinically indicated [(55)].

Mild/moderate may thus also be clinically defined as: persistent symptoms (e.g., headache, dizziness, neurocognitive, sleep, behavioral) for more than 6 months without evidence on standard or advanced neuroimaging studies (e.g., CT, MRI, DTI) of structural or microstructural damage (e.g., SAH, ICH, DAI, SDH, EDH). Neuropsychological testing may indicate abnormalities (e.g., decreased processing speed, executive function, attention and concentration, learning and memory) and may include a significant decrease from premorbid levels. There should be no evidence of feigning, symptom exaggeration, or fabrication and other possible causes of a patient's symptoms (e.g., medications, metabolic, substance abuse). Symptoms may worsen with cognitive and at times physical exertion. Severe TBI may be clinically defined by the same attributes as mild/moderate, with additional evidence of damage on neuroimaging. See Classification for more information.

Trigeminal Nerve: Damage to this nerve causes pain. TBI has a broad range of mechanisms and consequences of injury that may cause multiple types of pain that may include the trigeminal nerve. These mechanisms may or may not involve skull fractures and/or contusions [(124)]. The trigeminal nerve is the primary sensory nerve to the face. Patients with trigeminal neuralgia or pain in the area of the trigeminal nerves due to inflammation frequently have pain in one or more of the three branches of the cranial nerve: ophthalmic (V_1), maxillary (V_2), or mandibular (V_3). This pain may be dull, sharp, and/or shooting. with reduced reflexes and sometimes burning pain [(125)].

Visual Analog Scale: Visual Analog Scales (VAS) are figures of lines that are used to measure a patient's level of subjective pain. There are different types of VAS pain scales, but nearly all range in value from "0" or "no pain" to "10" or "worst pain" (or 0 to 100). Some have no numeric designation on them; instead a line is drawn between the extreme ends of the line noted as "no pain" and "severe pain" and the patient's "x" on the line is used to measure the fraction or distance between the ends. Some are 0 to 100mm in length. Some have additional verbal anchors such as "mild" and "moderate. " Despite these nuances, the performance of these various VAS scales is believed to be valid and reliable.

RISK AND CAUSATION

Traumatic brain injury affects nearly 69 million individuals globally and 3.17 million people in the United States every year [(18)]. An estimated 18% of these cases are work-related [(18, 126)]. Additionally, the mechanisms of TBI injury significantly differ in the workplace compared with the general population. Workplace TBI is more commonly a result of falling, being struck by an object, or machinery accidents compared with non-work-related TBI [(20, 22)]. Approximately 11.2% of TBI cases among workers in California are due to workplace violence [(29)]. A direct blow to the head is not required for a TBI to occur because rapid acceleration or deceleration is a TBI injury mechanism. Military populations incur both blast- and non-blast-related TBI [(127-130)]. The majority of work-related TBI cases are not fatal and

are considered mild [21, 131, 132]. Among 4.8 million patients evaluated in emergency departments for TBI in the general population, 31% had other head/face/neck injuries, 10% had spine and back injuries, 7% had torso injuries and 14% had extremity injuries [133].

A determination of the work-relatedness of TBI is generally simple. The employment context for the event determines the work-relatedness of the TBI (see Work-relatedness Guideline). Work-relatedness may become considerably more complex if there are long-term sequelae and a history of multiple events and some occurred at work while some occurred avocationally. In such cases, factors such as determination of which event(s) led to the disability and apportionment may arise in some jurisdictions. Nevertheless, caution is warranted in interpreting pre-compared with post-injury symptoms [134-146], as there is a propensity toward underreporting pre-injury symptoms especially in mild TBI cases as well as high rates of similar symptoms in non-concussed individuals [136, 139, 140, 142, 144, 146-148]. Those with worse TBI symptoms reportedly have the largest problem with this form of recall bias [149]. Persistence of symptoms after TBI has been shown to be increased in those who are older [138, 150, 151], female [149, 152], and had a more severe injury [138, 150, 151, 153]. Persistence of symptoms has been associated with alcohol [140, 150], drug use [140, 150], psychological/psychiatric history [140, 146, 150, 152], seeking compensation [146] and lower socioeconomic status [154]. Similar findings of worse outcomes with lower parental education, school achievement, and a history of learning problems, have been reported in pediatric patients with TBI [138, 151, 155].

The ability to distinguish mild TBI from controls is reportedly only moderately successful [156]. One case series found insufficient effort in 45% of workers compensation TBI cases [157] and other studies have highlighted similar problems with effort [158, 159]. Effort has been reported to be more important than TBI injury severity [160, 161, 162, 163, 164, 165]. Similarly, a patient's perception of adverse consequences after mild TBI and/or stress are also important in the ongoing perception of symptoms persistence [135, 141, 163, 166, 167]. Stress, psychiatric history, low social support, low intelligence, anxiety and depression have all been found to predict persistence of symptoms after TBI [149, 166, 168-171]. Lower rates of return-to-work status have been reported among those who are older, had a lower Glasgow Coma Score, had extremity injuries, had prior job instability, and have lower education [172].

INDIVIDUAL FACTORS

Male sex is a strong risk factor for TBI [12, 15, 18, 173-176]. Severity measures also indicate that men incur worse TBIs on average than women, as men accrued more lost work time and incurred higher average health care costs [177]. Age is another risk factor for TBI, with varying insults over the lifespan. A strong bimodal distribution is present with those in their teens and again those in the elderly years incurring far higher rates of automobile accidents [12, 178, 179]. Assaults are common among youth, while falls are increasingly common with advancing age [174, 179, 180]. Increasing age has been associated with a poorer outcome for TBI [12, 181]. Social support, education, social economic status, and age play a role in returning to work after TBI and the severity of injury is a strong determinant of (re)employability [182, 183]. Other risks, especially for delayed recovery include prior mental disorder(s), attention deficit disorder, ADHD, drug use, and pre-existing intellectual and physical disabilities [184]. There is no significant evidence yet shown for risks from lack of exercise, genetics [185], cardiovascular disease [186], and illness [187].

PSYCHOSOCIAL AND WORK ORGANIZATIONAL FACTORS

Work-related TBI may be accompanied by physical, emotional and psychosocial costs. Symptoms of depression or anxiety, sleep disturbance, fatigue, inability to function socially, and other physical problems are potential negative consequences following TBI [146, 182, 188, 189]. Psychosocial characteristics, such as symptoms of anxiety, depression, locus of control, and somatization have been used to assess impacts affecting those sustaining TBI [152, 190]. Sleep problems and fatigue commonly affect all categories of patients with TBI [191, 192]. Additional factors lacking quality evidence, yet thought to influence impacts of TBI and return to work include history of sexual abuse, job strain, occupational support, nonoccupational support, and job satisfaction.

Particularly after severe TBI injuries, obtaining another job or returning to work may be difficult due to the various emotional and/or physical problems [193]. Comparatively minimal emotional issues are reported after mild TBI [194], although a sizable minority report ongoing symptoms beyond 1 year [195]. After TBI, inadequately addressing safety, poor social support, and financial burdens of injury may all influence returning to work [196].

Research conducted on Iraqi war veterans (N=277) suffering from mild TBIs showed that most had attendant psychosocial difficulties such as underemployment, low income, marital problems, low community integration, and life satisfaction. These difficulties were often still present three years after the initial TBI [197]. Yet, it has also been reported that mild TBI is not adversely impacted by PTSD and other psychiatric disorders in veterans [198].

Clinical research suggests that most patients with pre-morbid employment with a perceived higher quality of life had a subsequently higher return to work probability, improved psychosocial characteristics, and better adjustments to physical ailments. In contrast, those with pre-morbid employment with a perceived lower quality of life, had a subsequently lower return to work probability, limited psychosocial changes, and limited changes to physical ailments.

JOB PHYSICAL FACTORS

Many patients with severe TBI experience long-term difficulties with behavior, physical mobility, and/or cognitive tasks when returning or attempting to work. Regarding physical mobility factors, patients may be limited in performing work-related tasks, as well as daily routine tasks. Yet, quality research into these factors is relatively sparse and likely hampered somewhat by the great diversity in clinical TBI presentations and persistent debilities.

The proportion of patients returning to work after TBI is difficult to estimate and likely biased by the likelihood of excluding at least some individuals with mild TBI, including those who never sought treatment; however, it has been estimated that approximately 40.7% of patients were employed at 1 year after injury [199]. TBI severity is a strong predictor as prospective cohort study data have shown that the 3- and 6-month return to work rates for mild TBI were 77.6% and 78.9%, with emotional problems being particularly predictive of failure to return to work [200]. One factor making return to work more difficult for some is the gradual expansion or enrichment of jobs to encompass greater tasks, including many requiring far higher cognitive demands and thus complexities of many jobs that are far greater than in prior decades.

Correlations between questionnaire(s), clinical assessment, physical examination, and self-assessment is needed to validate a patient's current physical limitations prior to determining a return-to-work status [201].

CLASSIFICATION

There are multiple definitions for TBI and there is no consensus definition. Three broad acuity categories of TBI are commonly used (mild, moderate, severe) and often these definitions are dissimilar. Although there are multiple definitions for all categories, mild TBI (mTBI) seems to have the greatest degree of variation in its definition. Some experts and many quality studies in the research literature equate mild TBI to concussion, although some do not. To provide a basis for discussion of patient treatment based on severity, while also recognizing there is potential overlap for some cases and that prehospital GCS is limited in its ability to predict outcomes [202], the following definitions are used in this guideline:

Mild TBI (mTBI, also referred to as "concussion" in the ICD system), is defined as including at least one of the following [55, 203]:

- The person was not unconscious or was unconscious for less than 30 minutes.
- Memory loss lasted less than 24 hours. ACRM uses the following: Complete or partial amnesia for events immediately following the injury (or after regaining consciousness). If post-traumatic amnesia cannot be reliably assessed (e.g., due to polytrauma or sedating analgesics), retrograde amnesia (i.e., a gap in memory for events immediately preceding the injury) can be used as a replacement for this criterion [55].
- The GCS was 13 to 15.

Complicated mild TBI [27, 204]

- Same criteria as mild TBI, except with evidence of intracranial bleeding on head CT scan (or MRI).
- For purposes of this guideline, it is not recommended to classify complicated mild TBI cases within the mild TBI category for either evaluation or treatment. Evidence suggests that the prognosis differs [205, 206].

Moderate TBI is defined as [203]:

- The person was unconscious for more than 30 minutes and up to 24 hours.
- Memory loss lasted anywhere from 24 hours to 7 days (see above).
- The GCS was 9 to 12.
- Intracranial bleeding is considered at least moderate in some systems (e.g., VA/DoD [56]).

Severe TBI is defined as [203]:

- The person was unconscious for more than 24 hours.
- Memory loss lasted more than 7 days (see above).
- The GCS was 8 or lower.

Mild TBI is generally relatively benign and self-limited; however, in a small percentage of cases, the symptoms persist. Most patients have resolution of symptoms over a period of a few days to a month. Symptoms have been shown to persist up to a year [207]. Some patients can display symptoms beyond 1 year post-injury [208-210]. Moderate TBI is generally longer lasting, with symptoms lasting weeks to a few months. Severe TBI includes those with persistent symptoms. Many patients with severe TBI incur at least some permanent impairment.

Other terms used to describe mild TBI include concussion, minor head trauma, minor TBI, minor brain injury, and minor head injury.

NICHD-supported research has found that the diagnosis of mild TBI (concussion) in practice uses inconsistent criteria and relies heavily on patients' self-reported symptoms. A patient with TBI is a person who has had a traumatically induced physiological disruption of brain function.

The above categories are not absolute. For example, most now suggest that those with an intracranial bleed but otherwise categorized as "mild" should be categorized as "complicated mild" [211, 212]. Others have suggested relying more heavily on neuropsychological impairment to classify severity [212] as well as for the determination of longer-term impairments [213].

MEDICAL HISTORY

Thorough medical and work histories and a focused physical examination (see General Approach to Initial Assessment and Documentation guideline) are sufficient for the initial assessment of a patient complaining of potentially work-related TBI. Findings of the medical history and physical examination may alert the physician to other pathology (e.g., not of TBI origin) that can present concomitantly. Such findings include fractures, intracranial hemorrhages, vision impairments, hearing impairments, central nervous system impairments, and peripheral nervous system impairments. In this assessment, certain findings, referred to as red flags, raise suspicion of serious underlying medical conditions (see Table 2). The absence of red flags and conditions rules out the need for special studies, referral, or inpatient care. During this time, spontaneous recovery is expected, provided any associated workplace factors are mitigated [214].

There also are potential psychological conditions and symptoms that may be confounding and/or interacting and should be evaluated, such as substances use, psychological/psychiatric disorders, PTSD, suicidality, childhood sexual abuse, hallucinations, or intoxication.

Because TBI clinical presentations are so varied, comprehensive medical histories and physical examinations are necessary to assess a patient's TBI [215]. This section will review the medical history, including the questions that should generally be asked. The diagnostic approach also needs tailoring to the specific patient, particularly as factors such as the patient's exact mechanism of injury, age, past medical history, underlying medical conditions, prior injury history, and genetic predilections all probabilistically adjust the diagnostic approach and prognoses [216].

The history, especially in patients with subacute and chronic TBI, may sometimes be unreliable [134, 136, 138-140]. Therefore, a suggested approach to consider is the following [217] 1) take into account the patient's current physical and emotional state, 2) establish historical

anchor points and/or memorable milestones, 3) decompose generic memories by finding distinctions from each other, and 4) obtain a retrograde clinical history, from recent to remote [139].

The Medical History Questionnaire provides a guide for obtaining a patient's history.

Caution is warranted in interpreting the history as there are reported problems with reliability for decision-making that may impact diagnosis, treatment, and return to work [95, 134, 136, 138-140, 218]. Under-reporting of pre-injury symptoms is reportedly problematic [136, 140]. Additionally, pre-injury conditions such as alcohol and drug use and the preexistence of psychological conditions and pre-existing pain have been shown to be recalled at significantly lower rates in comparison with preinjury medical records [140].

PHYSICAL EXAMINATION

The objective of the initial physical examination of the patient with TBI is to assess those physical and cognitive abnormalities that evaluate the magnitudes and possible causes of loss of function that were elicited during the medical history [219, 220]. Pertinent negatives are also sought. The overall initial impression is an important metric of functional status, as well as helping guide the speed of assessment(s) required. Evaluate cranial nerve VI for impaired function and fundoscopic examination for papilledema. Also, assess vital signs, such as elevated blood pressure, may suggest elevated intracranial pressure. Elevated temperature may suggest the presence of an infection. Tachycardia may be a sympathetic nervous system response to the patient's pain, a sign of increased intracranial pressure, or it may be anxiety related. For those being assessed after the initial trauma assessment, a comprehensive physical examination, neurological evaluation with consideration for eye tracking assessment, psychological evaluation and cognitive assessment should generally be performed [215]. For those undergoing more advanced testing for chronic TBI impacts, tachycardia may be relevant as indicating potential psychological disturbance, and illicit medication use.

1. **Vital Signs.** Assess vital signs. Assess postural changes in blood pressure and tachycardia as autonomic dysfunction may occur.

2. **Initial screen for cognitive impairment, examine scalp.** For those with impaired mentation, assess with the Glasgow Coma Scale. Next, assess orientation to person, place, time. Consider additional cognitive screening (e.g., recall of presidents, immediate/5-minute recall of 3 items). Palpate for boney step-offs and other signs of potential fractures. Predictors for estimating durations of loss of consciousness and post-traumatic amnesia are available [221].

3. **Vision and hearing screening examinations**. Assess eye opening. Screen for visual acuity and perception. Consider confrontational testing. Assess peripheral vision. Examine pupils, extraocular movements, funduscopic exam. Pupillary light reflex abnormalities is reportedly 95.1% specific and 78.1% sensitive [222]. Assess smooth pursuits and near point convergence. One comparative study suggested the best predictive value was in near point of convergence break and average dilation velocity [223]. Assess qualitative hearing. Perform otoscopic examination.

4. **Balance and vestibular examination.** Assess balance and vestibular functions. Consider Single leg stance, Balance Error Scoring System (BESS), Berg Balance Scale, Timed Up and Go, Vestibular/Ocular Motor Screening (VOMS) tool [224], and the Functional Gait Assessment. Assess sway on Romberg.

5. **Oral, facial examination.** Examine oral cavity. Examine facial structures.

6. **Cranial nerves.** Assess the remaining cranial nerves and exam, paying particular attention to those with evidence of potential damage (e.g., facial trauma, CN I re. cribiform plate).

7. **Neck exam.** Evaluate the cervical spine for trauma and/or fracture. Include gentle range of motion, pain with range of motion, muscle tenderness, and tender spinous processes.

8. **Examine heart, lungs.** Perform exams on the heart, lungs, abdomen and then any area with evidence of trauma. Evaluation for orthostatic hypotension, postural tachycardia in those with longer-term TBI [225, 226].

9. **Motor function.** Assess cooperation with motor testing. Assess motor strength in all major muscle groups. More specificity in assessing affected muscles in all areas of weakness or paralysis is generally next performed using the standard muscle grading scale. To the extent possible, identify the peripheral nerves or innervations for the weakened or paralyzed muscles, even when the weakness or paralysis is of central origin. Standard muscle grading scale: 0 = Absent No muscle movement felt. 1 = Trace Muscle can be felt to tighten, but no movement produced. 2 = Poor Muscle movement produced only with gravity eliminated. 3 = Fair Muscle movement produced against gravity, but cannot overcome any resistance. 4 = Good Muscle movement produced against some resistance, but not against "normal" resistance. 5 = Normal Muscle movement can overcome "normal" resistance. It is particularly important in patients with TBI to make an assessment of strength that incorporates expected strength based on muscle bulk. For example, strength is not the same across the lifespan (including differences based on differential aging impacts on proximal vs. distal and upper vs. lower extremities), between sexes, and include different body frames. Comparisons with an unaffected side, when possible, are particularly helpful. Yet, especially in chronic cases, poor effort has been reported [161, 164, 227].

10. **Muscle tone**, **reflexes.** Describe any muscle atrophy or loss of muscle tone. Examine and report deep tendon reflexes (usually 0-4 scale) and any pathological reflexes.

11. **Sensory function.** Describe exact location of any area of abnormal sensory function, noting methods of sensory testing used. Identify the peripheral nerve(s) that innervate the areas with abnormal sensation.

12. **Gait, spasticity, cerebellar signs**. Gait has been reportedly abnormal among those with TBI that may include mild TBI [220]. Describe any gait abnormality (if possible), imbalance, tremor or fasciculations, incoordination, or spasticity. If there is spasticity or rigidity (e.g., Ashworth Scale), assess any limitation of motion of joint (including joint contracture) by following the Joints examination protocol. (A tandem gait assessment (walking in a straight line with one foot directly in front of the other) is recommended.) Consider dual switching tests, such as tandem gait plus counting backwards from 100.

13. **Autonomic nervous system**. Describe any other impairment of the autonomic nervous system, such as orthostatic (postural) hypotension (if present, state if associated with dizziness or syncope on standing), hyperhidrosis, delayed gastric emptying, heat intolerance, etc.

14. **Cognitive impairment/Psychological Impairment.** Consider a Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), or Saint Louis University Mental Status (SLUMS) to perform a screen for cognitive impairment. Does the screening show problems with memory, concentration, attention, executive functions, mood, depression etc.? For subacute to chronic cases especially, a comprehensive neuropsychological evaluation is necessary [213, 215].

15. **Psychiatric manifestations**. Conduct a screening examination for psychiatric manifestations, including neurobehavioral effects particularly if there is a history of same.

16. **Skin**. Describe any areas of trauma or skin breakdown.

17. **Endocrine dysfunction.** If evidence of endocrine function is identified or suspected, select and follow the additional appropriate examination protocol for the type of endocrine disorder identified.

18. **Other abnormal physical findings.**

Because cervical spine trauma is a common accompaniment of TBI, the examination for the cervical spine is guided by the medical history and includes:

- General observation, including changes in positions, stance

- Gait while walking an extended distance, typically in the hallway, and changes in gait with distance walked
- Regional examination of the spine
- Examination of organ systems related to appropriate differential diagnosis
- Neurologic screening
- Testing for nerve root tension
- Monitoring pain behavior during range of motion and while seated as a clue to the problem's origin

The completely objective parts of the spine examination are circumferential measurements for atrophy or findings of fasciculations. All other findings require the patient's cooperation, although reflexes are generally more objective than subjective.

NEUROLOGIC SCREENING

Brain injuries may present with trauma to multiple body systems. It is important to consider spine and spinal cord injury when assessing brain injury. Patients may have symptoms of cervical pain and arm numbness and/or weakness like other patients with neck disorders. However, many also have additional symptoms of gait abnormality, leg numbness and/or weakness, or bowel/bladder control impairment.

Physical examination findings that correlate with significant myelopathy are:

- Hyperreflexia (Grade 3 or greater);
- Hoffman reflex (observing reflex flexion of the thumb distal phalanx when the distal phalanx of the middle finger is "flicked" or suddenly passively pushed into flexion at the DIP joint);
- Inverted brachioradialis reflex (during testing the brachioradialis reflex there is a decreased response from the brachioradialis and an abnormal flexion response of the fingers);
- Ankle clonus (forcefully dorsiflexing the ankle and maintaining pressure on the sole of the foot to maintain ankle dorsiflexion and observing for rhythmic beats of ankle flexion and extension, at least 4 "beats" required for sustained clonus to be abnormal);
- Babinski sign or reflex – firmly sweeping the pointed end of a reflex hammer from the lateral sole to the base of the toes and observing for an extensor response of the hallux (great toe);
- Cervical stenosis – while not a physical examination finding per se, it should be recognized that myelopathy is strongly linked to cervical stenosis, both congenital and degenerative, and other spinal conditions such as OPLL (ossification of the posterior longitudinal ligament, and ankylosing spondylitis.

The neurologic examination most commonly focuses on a few tests that reveal evidence of nerve root impairment, peripheral neuropathy, or spinal cord dysfunction. Cervical spine screening criteria include the Canadian Cervical Spine Rules and NEXUS [228, 229, 230, 231]. The most common herniated disc in the cervical spine is the C5-C6 disc with impingement of the C6 nerve root. The clinical features of cervical nerve root compression are summarized in Table 3.

1. **Testing for Muscle Strength**

There are no specific muscle tests for the C1 to C2 nerve roots.

2. **Circumferential Measurements**

Muscle atrophy is one of the few purely objective findings and can be measured with bilateral circumferential measurements of the upper arms and forearms at a fixed distance from an anatomic point (e.g., olecranon process). However, the dominant upper extremity usually may have an increase of up to 1 cm in circumference at the forearm and, possibly, also of the upper arm. Additional disparities in circumference are possible based on asymmetrical job physical requirements.

3. **Reflexes**

The biceps reflex primarily tests the C5 root, and to a lesser extent, the C6 root. The brachioradialis reflex tests the C6 root. The C7 root is assessed with the triceps reflex. The Hoffmann reflex in combination with clonus may indicate an upper motor neuron lesion, particularly if asymmetric. The presence of a jaw jerk (reflex) may be helpful in distinguishing physiological brisk reflexes from pathologic reflexes from a brain or spinal cord injury cephalad to the limbs being examined.

4. **Sensory Examination**

Testing to light touch and pinprick (sharp dull perception) in the forearm and hand is usually sufficient to detect common nerve root compromise, but it may be necessary to perform sensory examination of the area from the neck to the forearm to test for higher nerve root compromise. Decreased sensation over the lateral deltoid muscle is a sign of C5 nerve root or axillary nerve compromise. Loss of sensation in the area of the radial forearm and thumb (and perhaps the index finger) suggests C6 nerve root involvement. Decreased sensation in the middle finger (3rd digit) may be a sign of C7 involvement, although it also is supplied occasionally by the C6 or C8 nerve root. The C8 root may show ring and little finger sensory findings. The ulnar side of the little finger (5th digit) is the purest area of C8 innervation. The T1 nerve root can be tested by evaluating sensation in the upper medial forearm and medial arm. The examiner should determine whether light touch can be felt, and whether the patient can distinguish between sharp and dull stimuli. These findings are more reliable than the report that sensory stimuli feel odd or “different” to the examinee, and yet each sensory stimulus is perceived [(232)].

Bedside (or office) testing of sensory function referable to the brain includes cranial nerve deficits (loss of smell, vision or visual fields, hearing loss or balance issues, facial sensory or motor loss, dysarthria, or dysphagia). Cortical sensory representation can be tested using graphesthesia, stereognosis, or double simultaneous stimulation.

5. **Physical Examination Tests**

Ideally, the treatment of cervical or thoracic pain should be based upon a correct diagnosis. However, for most patients a specific diagnosis that indicates the pain generating structure and the pathophysiology is not possible, and their diagnosis is nonspecific cervical pain. Physical examination rules out major neurologic involvement and provides a baseline from which to judge improvement over time. For a variety of reasons, a patient’s response to a single test may not be reflective of the presence of identifiable underlying pathology.

RED FLAGS

Features of the patient’s history or examination that indicate the possibility of potentially serious disorders are referred to as “red flags. ” These include features that suggest the

possibility of intracerebral hemorrhages, increased intracranial pressure, central nervous system impairments, visual impairments, hearing impairments, skull fractures, spine fractures, acute dislocations, spinal infection, or serious or progressive neurologic deficit (see Table 2). While recognizing these red flag disorders is clearly important, there are no high-quality prospective cohort studies to provide the evidence base for this section of the guidelines.

Absent red flags, TBI can be classified into one of three working categories described in Classification.

MONITORING/AUDITING CRITERIA

The monitoring/auditing criteria are as follows:

1. Patients with TBI undergo a CT, or in select cases, an MRI on initial presentation if head trauma sufficiently forceful to potentially cause intracranial hemorrhage, epidural hemorrhage, subdural hemorrhage and/or other traumatic brain injury. Target 100%.
2. Patients with TBI diagnosed with subacute, severe or moderate TBI are prescribed amantadine 100 mg 2x/day, then 150 mg 2x/day at 14 days, and 200 mg 2x/day at week. (There is no recommendation for or against Amantadine therapy in patients with mild TBI.) Target 75%.
3. Patients with TBI are screened for depressive disorders. Target 100%.
4. Patients with TBI with functional deficits are prescribed a patient-specific exercise program that includes aerobic exercise and/or physical therapy/occupational therapy program that targets the deficits and gaps between current abilities and job tasks. Target 100%.

DIAGNOSTIC RECOMMENDATIONS

IMAGING

Most patients with mild TBI do not require advanced imaging [233]. For those patients needing acute diagnostic imaging, CT scan is the preferred test. There are common rules used to help guide CT screening, such as the Canadian CT Head Injury/Trauma Rule [234], the New Orleans/Charity Head Trauma/Injury Rule [235], and the NEXUS Head CT rule [236]. MRI is not used as a screening tool for acute TBI unless clinically and diagnostically indicated.

Non-imaging tests may be helpful to diagnose complications; however, other tests are not considered diagnostic of TBI (e.g., EEG, QEEG, computerized cognitive screening, eye findings, volumetric MRI).

ADVANCED IMAGING

For most cases of mild TBI, advanced imaging is not indicated at initial presentation [237, 238, 239]. When advanced imaging is indicated, it most commonly includes CT, MRI, MRS, and DTI. Computed tomography is often the best option for acute injuries that need advanced imaging, because of its speed and success at detecting life-threatening injuries. MRI is generally not indicated as the sole advanced imaging test for most acute TBI cases, although it is frequently used for subsequent imaging.

Magnetic resonance spectroscopy (MRS) is a noninvasive diagnostic tool similar to MRI with the additional capability of measuring the metabolite concentrations [240-249]. Functional magnetic resonance imaging attempts to assess neural function using blood oxygen level-

dependent (BOLD) contrast. BOLD utilizes hemodynamic factors, which include cerebral blood volume, metabolic rate of oxygen, and cerebral blood flow (CBF). When the increase in CBF exceeds cerebral metabolic rate the result is a higher ratio of oxygenated to deoxygenated hemoglobin [250]. The use of fMRI via BOLD contrast is thought to be sensitive to changes in neural activity after a traumatic brain injury [251-256]. Diffusion tensor imaging (DTI) is an advanced magnetic resonance imaging technique that is commonly used to evaluate patients with TBI [257-269]. DTI can be utilized to study the brain structure on a regional or whole-brain level, including to define white matter tracts [270]. Regional and whole-brain approaches use average diffusion values such as fractional anisotropy (FA) or apparent diffusion coefficient (ADC) is taken from voxels within the regions or tracts [270]. FA and ADC is the degree of water diffusion in the brain, which when resistance in the brain is absent, will yield higher ADC and lower FA values [271].

Gradient echo MRI is helpful for blood and remote hemosiderin, while also correlating with diffuse axonal injury (DAI) [272]. Grades of DAI commonly used are Grade 1, which is subcortical; Grade 2, which includes corpus callosum; and Grade 3, which includes the brainstem.

MAGNETIC RESONANCE SPECTROSCOPY (MRS) FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Magnetic resonance spectroscopy is selectively recommended for mild TBI cases with symptoms persisting for 3-6 months to help evaluate the differential diagnosis and whether mTBI remains the correct diagnosis. It is not recommended for all other mild TBI patients, as well as those with moderate or severe TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Mild TBI cases with symptoms persisting for 3-6 months to help evaluate the differential diagnosis with MR spectroscopy to assess whether mTBI remains the correct diagnosis. It is not recommended for all other mild TBI patients, as well as those with moderate or severe TBI.

Benefits

Confirm the diagnosis of persistent mTBI.

Rationale

Magnetic resonance and magnetic resonance spectroscopy have been used for the diagnosis of traumatic brain injury (Huang et al., 2024, Joyce et al., 2022, Dogahe et al., 2023, Eisele et al., 2020, Brown et al., 2018). There are quality studies assessing MRS for diagnosis of TBI. There is generally consistent, quality evidence that MRS findings are correlated with TBI (Tollard et al., 2009, Friedman et al., 1999, Signoretti et al., 2010, Yeo et al., 2011, Maudsley et al., 2015, Govind et al., 2010, Narayana et al., 2015, Sheth et al.,

2020, George et al., 2014, Mariano et al., 2017, Robayo et al., 2023, Sours et al., 2015). Small studies have also reported mostly similar findings (Vedung et al., 2022, Veeramuthu et al., 2018, Yasen et al., 2018, Davitz et al., 2019, Dogahe et al., 2023, Gardner et al., 2017, Gill et al., 2018, Johnson et al., 2012, Joyce et al., 2022, Kirov et al., 2013, Kontos et al., 2017, Lawrence et al., 2019, Panchal et al., 2018, Ruzinak et al., 2022, Hetherington et al., 2014), although negative studies have been reported (Cartwright et al., 2019).

There also is evidence that MRS findings are predictive of subsequent clinical outcomes (Tollard et al., 2009, Friedman et al., 1999). Systematic reviews note problems with inability and/or difficulty applying to mild TBI (Brown et al., 2018, Joyce et al., 2022) or acute TBI (Brown et al., 2018, Ruprecht et al., 2019). Another systematic review with meta-analysis based on only 101 patients found usefulness of MRS for patients with mild TBI using N-acetyl-aspartate, glutamate, and choline but not creatine (Eisele et al., 2020). Some evidence suggests intelligence factors may confound or interact with the MRS findings (Yeo et al., 2011). One comparative study reported higher sensitivity with SPECT than MRS (Dhandapani et al., 2014). Still, there is no quality evidence that MRS alters the clinical course beyond that already obtained from MRI or other imaging. There also remains a lack of consensus on the precise findings that are consistent with TBI.

MRS is not invasive has no adverse effects, is high cost, and has limited evidence of diagnostic efficacy. Yet, without quality evidence that it alters the clinical course, there is no recommendation for or against MRS for the diagnosis of mild, moderate or severe TBI. Magnetic resonance spectroscopy is selectively recommended for mild TBI cases with symptoms persisting for 3-6 months to help evaluate the differential diagnosis and whether mTBI remains the correct diagnosis.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Magnetic resonance spectroscopy, Nuclear magnetic resonance spectroscopy, NMR spectroscopy ; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 52 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 52 articles, 2 in CINAHL, 4 in Cochrane Library, 6980 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 1 from Cochrane Library, 16 from Google Scholar, and 0 from other sources. Of the 21 article considered for inclusion, 15 diagnostic studies and 6 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of

100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

FUNCTIONAL MAGNETIC RESONANCE IMAGING (FMRI) FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Functional MRI is selectively recommended for patients with mild TBI who have symptoms persisting for 3-6 months and specific task performance deficits (e.g., cognition, language, vision). For these patients, fMRI can help to evaluate the differential diagnosis and determine whether mTBI remains the correct diagnosis. It is not recommended for all other patients with mild TBI, or those with moderate or severe TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Mild TBI cases with symptoms persisting for 3-6 months and having specific task performance deficits (e.g., cognition, language, vision) to help evaluate the differential diagnosis and whether mTBI remains the correct diagnosis. MR spectroscopy is generally preferable as its purpose is similar and the cost is lower. Functional MRI is not recommended for all other patients with mild TBI, as well as those with moderate or severe TBI.

Benefits

Confirm the diagnosis of persistent mTBI.

Rationale

Functional MRI has been used for the diagnosis of traumatic brain injury (Ofoghi et al., 2020, Cook et al., 2020). There are few quality studies assessing functional MRI for the diagnosis of TBI (Mayer et al., 2015, Ramos-Zuniga et al., 2014, Dettwiler et al., 2014, Palacios et al., 2012, Madhavan et al., 2019). There also are many low-quality studies (Astafiev et al., 2016, Dean et al., 2015, Churchill et al., 2017, Johnson et al., 2015, Rockswold et al., 2019, Van Der Horn et al., 2016, Van Der Horn et al., 2017, Gao et al., 2013).

Although multiple studies show some abnormalities, such as in visual areas (Mayer et al., 2015) and multiple other brain regions/structures (Zhan et al., 2015, Wylie et al., 2015, Van Der Horn et al., 2017, Rockswold et al., 2019, Dean et al., 2015, Churchill et al., 2017, Astafiev et al., 2016), there is no consistent pattern of abnormalities that has as yet been clearly identified. Also with fMRI, no quality studies have shown that fMRI alters the clinical course compared with other diagnostic testing, such as acute-phase CT and traditional MRI. A systematic review found fMRI to be "expensive and time-consuming, making it difficult for regular use in everyday practice (Lunkova et al., 2021). Another systematic review noted fMRI has complex challenges involving patient heterogeneity and variations in scan time

after injury (Mayer et al., 2015). Most studies of fMRI have focused on working memory tasks rather than diagnostics (Jantzen, 2010).

Functional MRI is minimally invasive and has no adverse effects. However, it is very high cost, has no clearly defined and consistent brain region of abnormalities, and has no quality evidence on altering the clinical course. Therefore, it is only recommended for highly select cases of mild TBI with symptoms persisting for 3-6 months and having specific task performance deficits (e.g., cognition, language, vision) to help evaluate the differential diagnosis and whether mTBI remains the correct diagnosis. MR spectroscopy is generally preferable to functional MRI as its purpose is similar and the cost of MR spectroscopy is lower. Functional MRI is not recommended for all other patients with mild TBI, or those with moderate or severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: fMRI, functional MRI, Magnetic Resonance Imaging; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 4,116 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 4,116 articles, 45 in CINAHL, 110 in Cochrane Library, 18,300 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 6 from Google Scholar, and 0 from other sources. Of the 11 article considered for inclusion, 5 diagnostic studies and 6 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

DIFFUSION TENSOR IMAGING (DTI) FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Diffusion tensor imaging is sometimes recommended for the evaluation of patients with traumatic brain injury (TBI).

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Symptoms of mild TBI, especially when there is somewhat unclear severity and a need to perform imaging to assess ongoing symptoms to identify that there are no abnormalities consistent with TBI. May be indicated for selective use among patients with moderate TBI who have ongoing symptoms.

Benefits

Able to help identify existence of abnormalities consistent with TBI on imaging, as well as extent of abnormalities.

Harms

Potential for misinterpretation when all other tests are normal and then conclusion drawn that permanent injury based on DTI and/or SPECT alone. Potential for confounding based on other brain abnormalities, including confounding conditions and mental health disorders.

Frequency/Dose/Duration

One-time evaluation. Infrequently, a second evaluation may be helpful to assess progress and/or residual changes.

Rationale

Diffusion tensor imaging (DTI) has been used for the diagnosis of traumatic brain injury (Lindsey et al., 2023, Hunter et al., 2019, Wallace et al., 2018, Asken et al., 2018, Lees et al., 2021, Jang et al., 2022, Meyers et al., 2023). There are multiple quality studies assessing DTI for diagnosis of TBI. Most studies (Sidaros et al., 2008, Murugavel et al., 2014, Rutgers et al., 2008, Abdelrahman et al., 2022, Adam et al., 2015, Ghodadra et al., 2016, Hasan et al., 2014, Huang et al., 2022, Jang et al., 2022, Jolly et al., 2021, Kasahara et al., 2012, Kim et al., 2024, Main et al., 2017, Palacios et al., 2022, Stenberg et al., 2021, Veeramuthu et al., 2016, Yin et al., 2019, Yuh et al., 2014) (Meyers et al., 2023) suggest it may help identify abnormalities consistent with TBI injuries. Findings typically include white matter/tract abnormalities and microhemorrhages.

Comparative studies have reported DTI as more sensitive than MRI (Adam et al., 2015, Asturias et al., 2023, Chung et al., 2018). One study of NFL football players found that baseline DTI imaging was helpful for improving the interpretation sensitivity of post-concussive DTI images (Niogi et al., 2019). One study found a need to adjust results by age, sex and GCS (Betz et al., 2012). One study suggests DTI findings are clinically predictive (Kumar et al., 2009) and another suggests long lasting changes are identifiable with DTI (Farbota et al., 2012). However, the specificity is low, limiting its use. Numerous low-quality studies have also suggested that DTI is sensitive and helpful for evaluation of patients with TBI (Alhilali et al., 2017, Elsorogy et al., 2022, Gimbel et al., 2024, Hashim et al., 2017, Jacquens et al., 2024, Jorge et al., 2012, O'Phelan et al., 2018, Thomas et al., 2017, Veeramuthu et al., 2015, Vinet et al., 2024, Xiong et al., 2014). One study suggested diffusion kurtosis was superior to DTI (Gard et al., 2024). However, a review suggested that while the sensitivity is high, the specificity is insufficient (Asken et al., 2018). DTI is minimally

invasive, has no adverse effects, is high cost, and has some evidence of diagnostic efficacy, although there are problems with low specificity, and thus it is selectively recommended for evaluation of patients with TBI. However, there are many findings that might predate the TBI, so caution and context is required for proper interpretation.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Diffusion tensor imaging, DTI; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 353 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 353 articles, 3 in CINAHL, 19 in Cochrane Library, 15100 in Google Scholar, and 0 from other sources†. We considered for inclusion 11 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 25 from Google Scholar, and 0 from other sources. Of the 35 articles considered for inclusion, 28 diagnostic studies and 7 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

POSITRON EMISSION TOMOGRAPHY (PET) FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of positron emission tomography (PET) in the evaluation of patients with traumatic brain injury (TBI).

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Positron emission tomography has been used for the diagnosis of traumatic brain injury (Yu et al., 2023). There are few quality studies assessing PET for diagnosis of TBI (Rubin et al., 2023, Steiner et al., 2003, Coles et al., 2004), with some studies using fluorodeoxyglucose PET for mainly patients with mild chronic TBI (Heholt et al., 2024, Komura et al., 2019, Lippa et al., 2023, Terry et al., 2024, Yamaki et al., 2018). One study with both FDG-PET and fMRI showed increases in the right thalamus, with reductions in both the bilateral occipital lobes and calcarine sulci (Heholt et al., 2024). Another study reported glucose uptake reductions in the prefrontal areas but increases in the limbic areas (Komura et al., 2019). Another study reported differences in the hippocampi, left temporal lobe, parietal and occipital lobes that

correlated with specific funds (perceptual reasoning, processing speed, working memory for the three lobes, respectively) (Lippa et al., 2023). One study of blast-related mTBIs among veterans reported very high correlations (ROC AUC=0.859) between numbers of mTBI blasts among veterans compared with controls in the left palladium (Terry et al., 2024). One FDG-PET study among patients with severe TBI found increased glucose uptake was associated with increases in function such as wakefulness (Yamaki et al., 2018). Small studies of football players conflict regarding finding differences in p-Tau deposition (Dhaynaut et al., 2023, Stern, 2019). A small study of football players found differences in deposition of 11[C]OPA-713 (Rubin et al., 2023). A systematic review and meta-analysis found few studies, an association only with subdural hematoma and mortality, and a need for more research (Yu et al., 2023).

PET is not invasive, has no adverse effects, is low cost, has evidence suggesting potential diagnostic efficacy especially in mild TBI (Coles et al., 2004). However, the reported findings are wide-ranging involving many brain regions and structures. Thus, without clear delineation of the specific abnormalities compared with normal individuals, there is no recommendation for or against PET for diagnosis of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 173 articles, 3 in CINAHL, 10 in Cochrane Library, 17,400 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 3 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 1 from other sources. Of the 12 articles considered for inclusion, 9 diagnostic studies and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

DYNAMIC IMAGING

Single-proton emission computerized tomography (SPECT) or single-photon emission tomography (SPET) is a neuroimaging technique that detects cerebral blood flow (CBF) and brain metabolism. SPECT has been used for diagnostic testing in patients with TBI [273-278]. Positron emission testing (PET) is a test that attempts to demonstrate physiological or functional defects in the brain and has been used in patients with TBI [279-284].

In the acute setting, CT angiogram is particularly indicated for detecting vertebral and/or carotid artery dissection.

SINGLE-PHOTON EMISSION COMPUTERIZED TOMOGRAPHY (SPECT) FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of single-photon emission computerized tomography (SPECT) in the evaluation of patients with traumatic brain injury (TBI).

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are quality studies assessing SPECT for diagnosis of TBI. SPECT has been previously used to detect brain death (Munari et al., 2005), although that is no longer a typical use. Data are somewhat conflicting regarding the usefulness of SPECT. While quality data suggest SPECT is superior to CT for detecting parenchymal lesions, data conflict regarding whether SPECT is superior to MRI for detection of parenchymal TBI findings (Newton et al., 1992, Bavetta et al., 1994, Kant et al., 1997, Kato et al., 2022) or not superior (Joglekar et al., 2014). SPECT has been used to attempt to objectify subjective complaints (Romero et al., 2015, Lorberboym et al., 2002, Mitchener et al., 1997). A few studies suggest SPECT findings are predictive of clinical outcomes (Jacobs et al., 1994, Jacobs et al., 1996, Romero et al., 2015, Ichise et al., 1994, Hofman et al., 2001). SPECT is not invasive has no adverse effects, is high cost, has no clear evidence of diagnostic efficacy for TBI, and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Tomography, Emission-Computed, Single-Photon, SPECT; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 56 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 56 articles, 8 in CINAHL, 5 in Cochrane Library, 8640 in Google Scholar, and 0 from other sources†. We considered for inclusion 5 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 4 diagnostic studies and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles,

we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VASCULAR IMAGING

Vascular imaging tests are diagnostic tests that use high-frequency waves to view blood flow of vessels. These tests encompass a few different types including: arteriography, ultrasound, noninvasive vascular assessment, and brain acoustic monitor [285]. Digital subtraction angiography has been used to detect vessel injury after penetrating brain injuries [286]. Brain acoustic monitoring (BAM) has been used to aid in the evaluation of TBI [285]. BAM is designed to detect, amplify and display sound waves from the skull. The system consists of 2-cm circular sensor placed on the forehead, connected by wire to a signal conditioning box. Signals are collected and displayed in real time [285, 287-290].

VASCULAR IMAGING TESTS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Vascular imaging tests are selectively recommended for the evaluation of patients with traumatic brain injury (TBI). In the acute setting, CT angiogram may be helpful for evaluating severity, predicting operative success, determining prognosis, and guiding therapy related to insults such as vascular disruption, bleeding, vertebral artery dissection, and carotid artery dissection.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Symptoms and/or signs consistent with vascular injury, including for patients who have sufficient trauma and/or mechanisms of trauma to the head/neck to incur potential vascular injuries (Nguyen et al., 2017, Black et al., 2021), as well as for evaluating severity, predicting operative success, prognosis, and for guiding therapy related to insults such as vascular disruption, bleeding, vertebral artery dissection, and carotid artery dissection.

Benefits

Identify treatable condition(s) and prevent complications such as stroke.

Harms

Adverse effects of the procedure, including bleeding, vascular injury for the invasive procedures, and renal insults and allergic reactions when contrast is used.

Frequency/Dose/Duration

Usually only one assessment is needed. Tests include CT angiography, digital subtraction angiography, diagnostic ultrasound, arteriography, magnetic resonance angiography (MRA)

and CT. Most evidence suggests DSA is superior to CTA (Kik et al., 2022, Ares et al., 2019, Grandhi et al., 2017).

Rationale

Vascular imaging tests have been used for the diagnosis of traumatic brain injury (Nguyen et al., 2017, Kik et al., 2022). There are few quality studies assessing vascular imaging tests for TBI. Most quality studies assessed the utility of the tests to detect vascular injury in severely injured patients, suggesting some benefits from computed tomography angiography (CTA) (Müther et al., 2020, Kik et al., 2022, Shannon et al., 2021, Meyer et al., 2024, Tso et al., 2017, Ares et al., 2019, Chen et al., 2024). CT angiography is helpful to evaluate head or neck injury especially with neck fractures to assess vertebral artery occlusion or dissection; it is also helpful for carotid artery injuries related to basilar skull fractures (e.g., aneurysm, dissection, fistula). However, two studies recommended digital subtraction angiography for those with penetrating injuries (Meyer et al., 2024, Ares et al., 2019).

Digital subtraction angiography in another option, however it is more invasive (Meyer et al., 2024), although one study found CTA to have no additive benefits (Naraghi et al., 2015). Two other studies suggest DSA is preferred to CTA for penetrating injuries (Meyer et al., 2024, Ares et al., 2019). A systematic review found CTA had good specificity but low sensitivity compared with DSA for evaluation of blunt cerebrovascular injury (Kik et al., 2022, Ares et al., 2019, Grandhi et al., 2017). Vascular imaging tests are invasive, have adverse effects, are high cost, have some evidence of diagnostic efficacy in evaluating TBI, and are selectively recommended for diagnosis of vascular problems associated with TBI. In general, CTA is preferred for most injuries, but DSA appears superior to CTA for penetrating injuries (Kik et al., 2022, Ares et al., 2019, Grandhi et al., 2017).

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Vascular imaging tests, Angiography, Noninvasive Vascular Assessment, NIVA, Computed tomography angiography, CTA; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 568 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 568 articles, 4 in CINAHL, 9 in Cochrane Library, 13800 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 7 from Google Scholar, and 0 from other sources. Of the 10 articles considered for inclusion, 8 diagnostic studies and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles,

we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BRAIN ACOUSTIC MONITORING FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of a brain acoustic monitor in the evaluation of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are quality studies assessing BAM for diagnosis of TBI. The reported correlation between BAM signal measured early after admission and subsequent anatomic and functional evidence of TBI indicates a high sensitivity (93-100%), but quite low specificity (14-30%) (Dutton et al., 2005, Dutton et al., 2011). Thus, the false-positive rate is considerable and limits the utility of the technology. The BAM diagnostic test is not invasive, has no adverse effects, is low cost, has limited evidence of diagnostic efficacy, and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Brain acoustic monitor, BAM**;** traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 26 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 26 articles, 0 in CINAHL, 3 in Cochrane Library, 984 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BASIC IMAGING

Skull radiography has been used to diagnose fractures, and thus assessing in the evaluation of patients with TBI [291-293]. Computerized tomography (CT) has been used to evaluate

patients with TBI, especially in the acute presentation phase [213, 294-299]. Magnetic resonance imaging (MRI) has been commonly used to assess patients with both acute and chronic TBI [300, 301].

SKULL X-RAYS FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Skull radiography is recommended for the evaluation of patients with traumatic brain injury (TBI).

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Patients who sustained TBI involving high impact to the skull, especially with loss of consciousness and physical examination findings of potential fracture. However, if CT is planned, x-rays add little diagnostic value. X-rays are especially helpful in settings without availability of CT (Nugraha et al., 2024).

Benefits

Identification of fracture, which helps to suggest severity of the injury and potential severity of TBI. However, x-rays are less sensitive than CT scans.

Harms

Negligible.

Frequency/Dose/Duration

Generally x-rays are only obtained at presentation. Occasionally additional x-rays are obtained at follow-up; however, ongoing concerns about fracture are generally better addressed by CT. One study found no significant differences between a 2-view and 3-view film series (McGlinchey et al., 1998).

Rationale

Skull x-rays may be useful to detect fractures. Their utility and additive value is significantly diminished if there are both concerns about skull fracture and head CT is also performed (Nugraha et al., 2024). X-rays are better indicated in situations where imaging (CT, MRI) is distant or unavailable. X-rays have some evidence of limited utility in evaluation of TBI injuries with skull impacts, are low to intermediate cost, and thus are selectively recommended.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2017 to the present using the following terms: skull, skull xrays; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 2,291 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 2,291 articles, 2,288 in CINAHL, 30,137 in Cochrane Library, 17,500 in Google Scholar, and 0 from other sources†. We considered for inclusion 8 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 6 from Google Scholar, and 0 from other sources. Of the 14 articles considered for inclusion, 6 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMPUTED TOMOGRAPHY (CT) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Computed tomography (CT) is recommended for the evaluation of patients with acute traumatic brain injury (TBI).

Strength of evidence Recommended, Evidence (C)
Level of confidence High

Indications

Head trauma thought to be sufficiently forceful to potentially cause cranial fracture, intracranial hemorrhage, epidural hemorrhage, subdural hemorrhage and/or other traumatic brain injuries. Generally not indicated after the initial evaluation or for evaluation of patients with subacute or chronic TBI, as MRI is generally preferred for subacute to chronic brain parenchymal evaluation (Yuh et al., 2013, Gentry et al., 1988, Kara et al., 2008, Snow et al., 1986, Wilberger et al., 1987, Firsching et al., 1998, Orrison et al., 1994). A low-quality study reported predictors of an abnormal CT for mild TBI, including post-traumatic vomiting, post-traumatic amnesia, raccoon eyes, and Glasgow coma scale of <15 (Shafie et al., 2023). A second low-quality study indicated that patients with a GCS <15 should obtain a CT scan and be admitted (Metwali, 2022).

The New Orleans decision rule for indications for CT scans among those with Glasgow Coma Score of 15 are: headache, seizure, intoxication, short-term memory deficit, vomiting, aged >60yrs, or injury above the clavicles. The reported sensitivity is 100% and specificity of 24.5% (Smits et al., 2005).

The following are the Canadian Head CT rule for indications for CT scans among those with Glasgow coma Score of 13-15: high-risk are GCS<15 at 2 hrs post-injury, suspected skull fracture, any sign of basal skull fracture, vomiting at least twice, aged at least 65 yrs; medium risk are retrograde amnesia >30min, and dangerous mechanism (pedestrian vs. motorized vehicle, ejected from vehicle, fall from height >1m or 5 stairs). The reported sensitivity is 98.4% and specificity of 49.6% (Smits et al., 2005). There are limited mild TBI cases where the severity or loss of consciousness or combinations of risks (e.g., in the elderly) may result in a clinical determination that there is need for a CT scan.

Benefits

Identification of surgical emergencies, fractures, and assisting in identifying or suggesting the severity of the TBI. Generally considered superior to MRI for acute and unstable patients. Imaging scoring with the Helsinki score is reportedly superior to the Rotterdam and Marshall scores (Raj et al., 2014).

Harms

Radiological exposure. May miss non-hemorrhagic abnormalities for which MRI is superior to CT for evaluation (Yuh et al., 2013, Gentry et al., 1988, Kara et al., 2008, Snow et al., 1986, Wilberger et al., 1987, Firsching et al., 1998, Orrison et al., 1994).

Frequency/Dose/Duration

A second CT scan is only indicated in the acute TBI setting where there is neurological worsening (Stippler et al., 2017).

Indications for discontinuation

Generally only obtained at presentation or at the initial, comprehensive evaluation.

Rationale

There are many quality studies assessing CT for diagnosis of TBI (Yao et al., 2017, Williams et al., 2021, Ip et al., 2015, Rogan et al., 2022, Bindu et al., 2017, Orrison et al., 1994, Williams et al., 2013, Raj et al., 2014, Marshall LF, 1992, Wardlaw JM, 2002). The Helsinki scoring system is reportedly prognostic (Yao et al., 2017, Raj et al., 2014). Studies note a problem with overutilization among low-risk patients (Ip et al., 2015, Rogan et al., 2022). A moderate-quality study found CT perfusion was predictive (Bindu et al., 2017). CT findings alone have been found to predict mortality (Marshall LF, 1992), as well as part of predictive models including other findings (e.g., GCS, pupil reaction, presence of subarachnoid blood (Wardlaw JM, 2002, Thomas et al., 2009). A study found the addition of neurocognitive tests to add important information to CT results (Williams et al., 2013). A comparative trial found CT superior to MRI for detecting fractures, while MRI was superior for detecting contusions, epidural hematomas, subdural hematomas and white matter injuries (Orrison et al., 1994).

Low-quality studies also show mostly similar findings (Ananthaharan et al., 2018, Chawla et al., 2015, Dupuis et al., 2023, Jain et al., 2019, Korley et al., 2016, Metwali, 2022, Rafay et al., 2020, Shafie et al., 2023, Stippler et al., 2017, Shobeirian et al., 2021). One low-quality study using the Scandinavian Neurotrauma Committee guidelines has suggested that measurement of S100B may result in elimination of the need for CT scanning among many patients with mild TBI (Ananthaharan et al., 2018). CT is particularly useful for unstable patients with potential need of surgical intervention, with one quality study showing superiority to MRI for that purpose (Gentry et al., 1988).

CT is not invasive, has no adverse effects (other than radiation exposure), is high cost, has evidence of diagnostic efficacy, and thus is recommended for diagnosis and planning treatment for patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Positron Emission Tomography Computed Tomography, CT scan; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 850 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 850 articles, 392 in CINAHL, 148 in Cochrane Library, 24,000 in Google Scholar, and 0 from other sources†. We considered for inclusion 7 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 9 from Google Scholar, and 0 from other sources. Of the 16 articles considered for inclusion, 14 diagnostic studies and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MAGNETIC RESONANCE IMAGING (MRI) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Magnetic resonance imaging is recommended for the evaluation of patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence High

Indications

Head CT is the preferred test for the evaluation of acute TBI, as CT is superior to MRI for detection of fractures and is generally preferred for evaluating acute TBI injuries to assess the need for surgery (Gentry et al., 1988). Subsequently, MRI is generally indicated for head trauma thought to be sufficiently forceful to potentially cause intracranial hemorrhage, epidural hemorrhage, subdural hemorrhage, and/or other traumatic brain injuries (Yue et al., 2019). May also be indicated as a follow-up MRI study for evaluation of ongoing symptoms, to assess a missed diagnosis, and/or resolution of prior defects.

Benefits

Identification of severity of white matter injuries, hemorrhages, and/or need for surgery (e.g., after early CT did not identify a surgical condition).

Harms

May have the potential to mislead regarding prognosis, as minor abnormalities are common and there is some evidence that clinical findings are superior to only MRI findings (Hughes et al., 2004, Lui et al., 2014).

Frequency/Dose/Duration

Generally only obtained early in the evaluation and treatment of patients with TBI
Sometimes a second MRI is obtained to evaluate ongoing symptoms to assess a missed or secondary diagnosis.

Rationale

There are multiple moderate-quality studies suggesting MRI is valuable for the evaluation of patients with TBI with MRI reportedly superior to CT for assessing intracranial injuries and white matter injuries, especially those without hemorrhage (Yuh et al., 2013, Gentry et al., 1988, Kara et al., 2008, Snow et al., 1986, Wilberger et al., 1987, Doshi et al., 2015, Einarsen et al., 2019, Griffin et al., 2019, Ly et al., 2022, Chiara Ricciardi et al., 2017, Tate et al., 2017, Toth et al., 2013, Trifan et al., 2017, Yue et al., 2019). MRI findings have been found to be prognostic for outcomes (De Haan et al., 2017, Griffin et al., 2019, Hageman et al., 2022). A comparative trial found CT superior to MRI for detecting fractures, while MRI was superior for detecting contusions, epidural hematomas, subdural hematomas and white matter injuries (Orrison et al., 1994). Some studies have not found superiority of MRI to CT for evaluation of hemorrhages, but these are also the oldest studies using weaker magnets (Gentry et al., 1988, Snow et al., 1986). One study reported utility of MRIs include evaluation of patients with negative CT findings (Wilberger et al., 1987). MRIs are not invasive (or minimally invasive with IV contrast), have no adverse effects, are high cost, but are helpful in diagnosing extent of injuries and identifying surgical conditions and are thus recommended for evaluating patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Magnetic Resonance Imaging, MRI; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 4494 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 4494 articles, 127 in CINAHL, 250 in Cochrane Library, 19,400 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 4 diagnostic studies and 4 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ULTRASONOGRAPHY FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Ultrasonography is selectively recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Head trauma thought to be sufficiently forceful to cause potential skull fracture.

Benefits

Identification of fracture, particularly in the emergency department and urgent care with ready access to US, which helps to suggest severity of the injury and potential severity of TBI.

Harms

Negligible

Frequency/Dose/Duration

Generally only obtained at presentation.

Rationale

Ultrasound (US) has been used for the diagnosis of traumatic brain injury (Xu et al., 2023). There are no quality studies assessing ultrasonography for diagnosis of TBI in the mild to moderate TBI population. There are quality acute, severe TBI studies that used US to assist in monitoring intracranial pressure such as through daily optic nerve monitoring (Agrawal et al., 2020, Altayar et al., 2021, Damor et al., 2021, Xu et al., 2023). Ultrasonography is not invasive has no adverse effects, is low cost, has evidence of diagnostic efficacy, and is recommended for diagnosis of skull fractures associated with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Ultrasonography, Ultrasound, US; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 11,285 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 11,285 articles, 80 in CINAHL, 40 in Cochrane Library, 26,000 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 1 diagnostic study and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ATTENTION TESTS

Studies have shown that various aspects of attention are affected following TBI, especially after severe TBI. These deficits include the ability to initially attend to and encode information [302], information processing speed [303, 304], maintain focus [304, 305], shift attention [306], attention span [304], supervisory attentional control [304], focused/selective attention [304], and sustain attention [304, 307]. Age was not found to be a significant factor by some [304] but not all studies [308]. However, Ginstfeldt [309] found that sustained attention was most vulnerable to TBI in children. There are many studies that have used attention testing in the evaluation of patients with TBI [310-329].

ATTENTION TESTS FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Attention tests are recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)

Level of confidence Moderate

Indications

Patients with TBI experiencing cognitive difficulties that include attention. May be used to screen among those without overt cognitive difficulties. May be performed to help guide treatment. May later be performed as part of an evaluation for end-of-healing and clinical plateau.

Benefits

Identify and measure attention difficulties, potentially allowing better tailoring of therapies to address any memory deficits.

Harms

Negligible in most patients. Testing is strongly subject to effort. Thus, careful interpretation and potential pairing with tests for effort are indicated especially where there is strong potential for secondary gain(s).

Frequency/Dose/Duration

Generally not performed more than once or twice. May be used to target specific cognitive rehabilitation strategies. May later help determine end of healing and extent of residual deficits, if any.

Rationale

Attention tests have been used for the diagnosis of traumatic brain injury (Farnsworth et al., 2017). There are many quality studies assessing various attention tests for diagnosis and evaluation of TBI (Fuller et al., 2021, Harmon et al., 2024, Karr et al., 2020, Lennon et al., 2023, Louey et al., 2014, Sullivan et al., 2018, Twamley et al., 2014). However, there are few comparative trials of sufficient size and rigor to allow a recommendation of one type of testing over another.

A moderate-quality cohort study found an association at baseline between history of TBI and poorer attention, processing speed, and working memory (Lennon et al., 2023). One moderate-quality study found the SCAT-5 to be accurate, although the components required interpretation when making a diagnosis of concussion (Harmon et al., 2024). One moderate-quality study found the modified Stroop test to be effective but the Abridged Spatial Memory and Trail Making Trial-B tests did not discriminate between non/concussed rugby players (Fuller et al., 2021). A moderate-quality study found multiple tests did not differentiate those with complicated from uncomplicated concussion (i.e., Paced Auditory Serial Attention Test, Taiwanese Word Sequence Learning Test, a semantic Verbal Fluency Test, Post-Concussion Symptoms, Beck Depression and Anxiety Inventories) (Karr et al., 2020)

Low-quality studies have shown similar diverse results (de Freitas Cardoso et al., 2019, Esopenko et al., 2022, Guty et al., 2021, Molloy et al., 2017, Moran et al., 2023, Sekely et al., 2018, Rogers et al., 2015, Waljas et al., 2014, Oldenburg et al., 2016, Nash et al., 2014, Dockree et al., 2015, Johansson et al., 2015, Maki-Marttunen et al., 2015, Zimmermann et al., 2015, Cicerone, 2002, Kurča et al., 2006, Nolin et al., 2006, Pastorek et al., 2004, Willmott C, 2009, Withaar et al., 2003, King, 1996, Chan, 2005, French et al., 2014, Niemann et al., 1990, Tramontana et al., 2014). Evidence of cognitive impairment (including MMSE, Frontal Assessment Battery for naming, incidental memory, immediate memory, learning, and delayed recall) after mild TBI has been noted in a low-quality study (de Freitas Cardoso et al., 2019).

Attention testing is not invasive, has no adverse effects, is low cost, and has evidence of diagnostic efficacy. Thus, it is recommended for evaluation of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Neuropsychological Tests, Attention tests; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 1706 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 1706 articles, 186 in CINAHL, 222 in Cochrane Library, 19,300 in Google Scholar, and 0 from other sources†. We considered for inclusion 6 from PubMed, 5 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 14 articles considered for inclusion, 12 diagnostic studies and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

AUDIOMETRY AND OTOLOGY

Damage to the hearing structures is a common effect of TBI. Conducting audiological tests to assess the level of damage may be useful in identifying hearing impairments and other disorders affiliated with TBI [(330)]. Brainstem auditory evoked response is a test that produces information about specific brain function [(331)]. The test has been used for assessing traumatic brain injury when standard behavioral audiometry was not possible due to mechanism of injury [(332)]. BAER has also shown usefulness in monitoring auditory nerve and brainstem dysfunction [(333)]. Tympanometry is a method for assessing the current state of the tympanic membrane, the ossicles and attachments, and the air cushion of the tympanic cavity within the ear [(334)]. It is commonly used to diagnose hearing loss [(334)].

AUDIOMETRY FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Audiometry is recommended for use in the evaluation of patients with traumatic brain injury (TBI).

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

TBI with reduced hearing or tinnitus, especially but not solely if the mechanism of injury was a blast. There is a low threshold for screening all patients with TBI with audiometry.

Benefits

Identification and quantification of hearing deficits that may help define the severity of the TBI. Potential to identify candidates for hearing aids.

Harms

Negligible. However, there is little quality evidence of effective treatments other than hearing aids.

Frequency/Dose/Duration

Baseline measure. May need second assessment at end of healing.

Rationale

Audiometry has been used for the diagnosis of traumatic brain injury (Chen et al., 2018, Šarkić et al., 2019). Symptoms and impairments regarding hearing and audiometry findings are common among patients with TBI (Knoll et al., 2020, Chen et al., 2018, Bansal et al., 2022, Vander Werff et al., 2019, Stahl et al., 2024). However, there are few quality studies assessing audiometry for diagnosis and evaluation of TBI. Audiometry is not invasive, has no adverse effects, is low cost, and has evidence of diagnostic efficacy. Therefore, it is recommended for the diagnosis of hearing impairments from TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Audiometry, Hearing Test; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 32 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 32 articles, 1 in CINAHL, 0 in Cochrane Library, 7970 in Google Scholar, and 0 from other sources†. We

considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 6 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 5 diagnostic studies and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BRAINSTEM AUDITORY EVOKED RESPONSE FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Brainstem auditory evoked response is recommended for use in the evaluation of patients with traumatic brain injury (TBI).

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Severe TBI with inability to test auditory system with more common methods, such as bedside testing, or audiometry.

Benefits

Ability to assess the auditory system.

Harms

Negligible.

Frequency/Dose/Duration

May be used at baseline. If there are abnormalities and the injury continues to preclude other testing, then follow-up testing with auditory evoked potentials is reasonable.

Indications for discontinuation

Resolution of TBI, improvement sufficient to undergo standard audiometric testing.

Rationale

There are no quality studies assessing brainstem auditory evoked response for diagnosis or evaluation of TBI, although there are low-quality studies (Meehan et al., 2019, Vander Werff

et al., 2017). Brainstem auditory evoked response is not invasive, has no adverse effects, is low cost, and appears to have utility to assess the hearing system. Therefore, it is recommended for selective use to assess the hearing system when other more common testing is not possible.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: ; brainstem audiometry evoked response, traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 2 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 2 articles, 2,362 in CINAHL, 764 in Cochrane Library, 2,040 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 2 diagnostic studies and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

TYMPANOMETRY FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of tympanometry in the evaluation of patients with TBI. There are other potential indications such as conductive hearing loss, acoustic neuroma, suspected ear effusion, and Eustachian tube dysfunction.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies assessing tympanometry for diagnosis of TBI. Tympanometry is not invasive, has no adverse effects, and is low cost. However, in the absence of quality evidence of diagnostic efficacy, there is no recommendation for evaluation of TBI. There are other potential indications such as conductive hearing loss, acoustic neuroma, suspected ear effusion, and Eustachian tube dysfunction.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Tympanometry; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 5 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 5 articles, 0 in CINAHL, 0 in Cochrane Library, 1,320 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BIOMARKERS

Biomarkers are under investigation as potentially predictive tools, particularly to supplement clinical assessment and neuroimaging tests [335, 336]. Biomarkers with some evidence of associations with TBI include autoantibodies against proteins, lipids, peptides, proteins, and RNA. Proteins studied include S-100 [337-341]. Reduced copeptin has been associated with TBI [342]. Galectin-3 and occludin [342] have been associated with TBI. Problems with biomarker measurements include technical and instrumentation methods that require further development [336], as well as that: (1) many studies only focus on one marker, measured at a single time point, as opposed to multiple markers over the course of recovery, which has led to poor replicability of findings; and (2) some biomarkers are sensitive but their specificity is typically poor.

Some data suggest that biomarkers may be associated with longer-term negative outcomes from TBI. While there is considerable evidence that biomarkers are associated with TBI, how measurement of these substances alters the management of patients with TBI is unclear and thus there is no recommendation for or against biomarkers. Quality studies showing biomarkers impacting the management of patients are needed. Another potential use is to identify resolution of TBI [343], yet that too requires more sensitive methods and further investigation.

BIOMARKERS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against use of biomarkers for the detection and/or management of TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There is a growing body of evidence for the potential use of many different biomarkers, including axonal protein neurofilament light (NFL), beta-amyloid, chemokine (C-X3-C motif) ligand 1, cleaved-tau, creatinine/cystatin C ratio, D-dimer, fibroblast growth factor 21, fractalkine, glial fibrillary acidic protein, insulin-like growth factor 1, insulin-like growth factor binding protein 5, Interleukin-6, interleukin-7, interleukin-8, macrophage chemotactic protein-1, microRNAs, neuron-specific enolase, S100B, sulfonylurea receptor-1, and tumor necrosis factor superfamily member 14, ubiquitin carboxy-terminal hydrolase-L1) from multiple sources (i.e., serum, urine, cerebrospinal fluid, saliva) for TBI.

Most of the evidence concerns whether there is an association between specific biomarker(s) and various measures of TBI, as well as with aging, exertion. and degenerative neurological disorders (Ahmadi et al., 2023, Di Battista et al., 2018, Cox et al., 2018, Lagares et al., 2023, Mondello et al., 2021, Mozafari et al., 2020, O'Connell et al., 2020, Oris et al., 2023, Oris et al., 2024, Oris et al., 2024, Oris et al., 2021, Peters et al., 2017, Richard et al., 2021, Rogan et al., 2022, Sharma et al., 2017, Thompson et al., 2020, Wang et al., 2019, Yakoub et al., 2018, Zetterberg et al., 2019, Brahmajothi et al., 2020, Cheng et al., 2019, Dey et al., 2017, Hamdeh, 2018, Hardy et al., 2017, Jiang et al., 2020, Jha et al., 2017, Johnson et al., 2018, Marklund et al., 2021, Goyal et al., 2021, Lithgow et al., 2018, Papa et al., 2019, Petrone et al., 2017, Petrone et al., 2017, Shahim et al., 2022, Shahim et al., 2017, Rubenstein et al., 2017, Taghdiri et al., 2019, Vedantam et al., 2021, Hanas et al., 2019, Simpson et al., 2024, Kayalar et al., 2024, Frankel et al., 2019, Korley FK, 2022).

A high-quality study of pre-and in-hospital SB100 suggested some utility to rule out intracranial lesions among those with mTBI, although in-hospital measures were more helpful, which also suggests limitations to the use to obviate need of CT scanning (Seidenfaden et al., 2021). One high-quality comparative study found serum ubiquitin carboxy-terminal hydrolase-L1 to modestly outperform glial fibrillary acidic protein and S100B for the purposes of screening within 6 hours of suspected TBI to potentially reduce use of CT scanning (Welch, 2016), although a secondary analysis found comparable areas under the curve (AUCs) for the sensitivity to detect mTBI (Lewis et al., 2017). Another study also found the utility of measuring S100B was sufficiently poor to be unable to reduce need of CT scanning (Blais Lécuyer et al., 2021). While evidence of elevated S100B has been elsewhere demonstrated, urine measurement was found to be less sensitive (Le Sage et al., 2019). SB100 was reportedly elevated compared with both baseline measurements and controls in a sports-related concussion study of high school and college athletes (Meier et al., 2020), and elevated SB100 is reportedly associated with worse outcomes (Osier et al., 2018).

Multiple high-quality studies found glial fibrillary acidic protein in the acute evaluative process to have evidence of being of some assistive in diagnosing mTBI (Yue et al., 2019, Papa et al., 2023, Papa et al., 2022), and one study suggested glial fibrillary acidic protein to outperform S100B (Okonkwo et al., 2020). GFAP helped distinguish concussed athletes from controls (McCrea et al., 2020), and GFAP was also associated with return to sport (Pattinson et al., 2020) and modestly better prognosis (Korley FK, 2022). One study found decreased glial fibrillary acidic protein and increased ubiquitin carboxy-terminal hydrolase-L1 compared with baselines among collegiate football players (Bazarian et al., 2023), thus

providing another important potential confounder in clinical evaluations. One large study found UCH-L1 associated with modestly better prognosis (Korley FK, 2022). A study of patients with sports-related concussions found that GFAP levels were not elevated compared with baseline and controls (Meier et al., 2020). GFAP was found to be associated with imaging abnormalities (Gill et al., 2018, Giza et al., 2021), and prognostic among those with mTBI (Forouzan et al., 2021, Giza et al., 2021).

A high-quality study (Papa et al., 2022, Papa et al., 2023) and multiple moderate-quality studies (Bazarian et al., 2018, McCrea et al., 2020) found ubiquitin carboxy-terminal hydrolase-L1 to be helpful in the diagnosis of mTBI. Ubiquitin-carboxy-terminal hydrolase-L1 is reportedly prognostic after concussion (Giza et al., 2021, Meier et al., 2020). One high-quality study suggested emergency department measurement of biomarkers (i.e., glial fibrillary acidic protein, ubiquitin carboxy-terminal hydrolase L1, microtubule-associated protein-2) were of additive benefit to clinical measures as being predictive of outcomes (Anderson et al., 2020). mRNA measures were not found to be predictive (Mitra et al., 2023).

One study suggested there was neither predictive value of baseline measurement nor longitudinal association between four biomarkers (i.e., cleaved-tau, glial fibrillary acidic protein, neuron-specific enolase, S100B) and post-concussive symptoms (Boucher et al., 2023). A low-quality case series of professional athletes who had repeated TBI and persistent post-concussion syndrome found total-tau, beta-amyloid, glial fibrillary acidic protein to not be correlated with CSF measures (Shahim et al., 2022). A moderate-quality case series of veterans suggested neurofilament light (NFL) chain was associated with repetitive mTBI (Guedes et al., 2020), and another suggested the NFL levels were elevated among older adults with uncomplicated mTBI (Iverson et al., 2019). NFL has been associated with sports-related concussion (Shahim et al., 2018) and other TBIs (Shahim et al., 2020). One RCT analyzed biomarkers and found reductions in biomarkers attributed to propranolol (El-Menyar et al., 2024).

IL-6 found to be correlated with CT-negative mTBI (Reyes et al., 2023), as well as duration of symptoms (Nitta et al., 2019). A moderate-quality study found an association of IL-6 levels with concussion among military combat personnel at less than 8-hours after injury (Edwards et al., 2020).

Salivary RNA biomarkers were found to predict concussion duration and detect symptom recovery (Fedorchak et al., 2021).

Thus, there are many high- and moderate-quality diagnostic studies of various biomarkers with many unsurprisingly showing elevated findings among those with TBI. However, the role and timing of the use of biomarkers, as well as the cutpoints for defining abnormal values, for the detection, additive value augmenting imaging findings, management, severity and stage of TBI are uncertain (Ooi et al., 2022, Mondello et al., 2021, Hiskens et al., 2022, O'Connell et al., 2018, Rogan et al., 2022, Karantali et al., 2022, Ahmadi et al., 2023). While there is a growing body of evidence of associations between biomarkers and TBI, the role of these biomarkers in the management of TBI remains to be developed and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Ultrasonography, Ultrasound, US; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 919 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 919 articles, 57 in CINAHL, 40 in Cochrane Library, 20,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 74 from PubMed, 13 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 77 articles considered for inclusion, 71 diagnostic study and 6 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

EXECUTIVE FUNCTION TESTS

Executive functions are "higher-order supervisory processes that initiate, maintain or inhibit other cognitive processes to facilitate goal-directed behavior" [344, 345]. Many types of executive function testing have been used to assess executive function in patients with traumatic brain injury [110, 346-354].

EXECUTIVE FUNCTION TESTING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Executive function tests are recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Patients with moderate or severe TBI experiencing cognitive difficulties that include executive functions. Patients with mild TBI are expected to have no durable executive dysfunction (Ord et al., 2010), but may be indicated in select circumstances where these is ongoing impairment. May be performed to help guide treatment. May later be performed as part of an evaluation for end-of-healing and clinical plateau. Selective use among those with mild TBI with ongoing difficulties, high and critical occupational cognitive-executive demands, and/or executive function complaints may also be indicated.

Benefits

Identify and measure executive function difficulties, potentially allowing better tailoring of therapies to address any deficits.

Harms

Negligible in most patients. Testing may be subject to feigning. Thus, careful interpretation and potential pairing with tests for feigning are indicated, especially where there is strong potential for secondary gains.

Frequency/Dose/Duration

Generally not performed more than once or twice. May be used to target specific cognitive rehabilitation strategies. May later help to determine end of healing and extent of residual deficits, if any.

Rationale

Many quality studies have assessed various executive function tests for the diagnosis of TBI (Adjorlolo, 2016, Adjorlolo, 2018, Cossette et al., 2014, Clarke et al., 2012, Morton et al., 2010, Paxton et al., 2014, Ponsford et al., 2008, Jelcic et al., 2013, Muller et al., 2010, Simmons et al., 2014, Baum et al., 2017, Potvin et al., 2022, Pinasco et al., 2023, Panwar et al., 2019, Lunter et al., 2019, Hacker et al., 2024). However, there are few comparative trials of sufficient size and rigor to allow a recommendation for one type of testing over another.

A meta-analysis concluded that the best tests were the Trail Making Test B followed by the Wisconsin Card Sorting Test (Krynicki et al., 2023). Another systematic review found construct validity for several instruments, but insufficient evidence for validity and reliability of measuring executive functioning longitudinally for any single instrument (D'Souza et al., 2019). Executive function testing is not invasive, has no adverse effects, is low cost, and has some evidence of diagnostic efficacy; therefore, it is recommended for the evaluation of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Executive Function Test, Executive Function Tests, Executive Dysfunction Tests; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 129 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 129 articles, 47 in CINAHL, 1 in Cochrane Library, 569 in Google Scholar, and 0 from other sources†. We considered for inclusion 10 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 6 from Google Scholar, and 0 from other sources.

Of the 16 articles considered for inclusion, 14 diagnostic studies and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

INTRACRANIAL PRESSURE TESTS

Intracranial pressure monitoring and cerebral perfusion pressure monitoring are used to measure blood flow within the brain and adjust therapy to attempt to maintain sufficient cerebral perfusion in patients with TBI [355-359].

INTRACRANIAL PRESSURE MONITORING AND THRESHOLDS FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Intracranial pressure monitoring is recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Moderate

Indications

Severe TBI injuries with concerns for inadequate cerebral perfusion due to intracerebral pressure.

Benefits

Potential to alter treatment to raise or maintain sufficient cerebral perfusion.

Harms

Infections, bleeding, further brain tissue damage

Frequency/Dose/Duration

Early patient monitoring until either there are no episodes of elevated intracerebral pressure, episodes of elevated intracerebral pressure have ceased, and/or intracerebral pressure is thought to not be problematic.

Rationale

Intracranial pressure monitoring and thresholds have been used for the diagnosis of traumatic brain injury (Godoy et al., 2022, Wang et al., 2021, Haider et al., 2018, Han et al., 2022, Stein et al., 2023). Studies consistently demonstrate correlations between intracranial pressure and clinical outcomes (Smith, 2008, Kuo et al., 2006, Narayan et al., 1981, Kahraman et al., 2011, Kirkness et al., 2005). Intracranial pressure monitoring is invasive, has adverse effects, is high cost, has some evidence of efficacy, and thus is selectively recommended for treatment and monitoring of some patients with severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Intracranial pressure monitoring, Intracranial pressure thresholds; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 565 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 565 articles, 9 in CINAHL, 49 in Cochrane Library, 4090 in Google Scholar, and 0 from other sources†. We considered for inclusion 30 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 12 from Google Scholar, and 0 from other sources. Of the 43 articles considered for inclusion, 37 diagnostic studies and 6 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

LABORATORY TESTS

Injury severity and medications dictate testing in the patient with TBI. In moderate and severe TBI, electrolyte status usually needs close monitoring. Complete blood counts and coagulation studies are also required. The cerebrospinal fluid (CSF) contains biomarkers that may be present after acute injury, signaling a pre-CTE (chronic traumatic encephalopathy) state and assisting in clinical treatment and guiding prognosis [360]. Also, because approximately 15-20% of MTBI cases involve hypopituitarism, endocrine tests are commonly required; in such cases, electrolytes should be closely monitored because concomitant syndrome of inappropriate antidiuretic hormone [361-365] and hypopituitarism are common [366].

LUMBAR PUNCTURE

Lumbar puncture (LP) is performed to examine cerebrovascular fluid in cases of injury and disease for signs of hemorrhage [367-372]. It is the most common test performed to evaluate signs of infection; thus in patients with TBI, it is probably most commonly used after penetrating injury when fever occurs and there are concerns about meningitis. LP is also

performed to identify blood in the cerebrospinal fluid from subarachnoid hemorrhage and a negative CT scan. However, this procedure has inherent risks and is not recommended for acute spinal cord trauma, elevated intracranial pressure, bleeding problems, and epidural abscess. If there is suspicion of elevated intracranial pressure, a funduscopic examination should generally occur initially followed by MRI or CT.

NEUROLOGICAL TESTS

ELECTROENCEPHALOGRAPHY

Electroencephalography (EEG) has been used to detect brain activity, propensity towards seizures, and has been used in the evaluation of patients with TBI [373-380]. Quantitative electroencephalogram is the mathematical analysis of electroencephalography and has been used to assess brain activity among patients with TBI [373-380].

ELECTROENCEPHALOGRAPHY (EEG) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Electroencephalography (EEG) is recommendation for use to diagnose seizures among patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence High

Indications

Known or suspected TBI injury. Evaluation of seizure-like activity or evaluation of risk of seizures. Generally required for those with penetrating head injuries and intracranial bleeds. May include sleep-deprived EEG, especially if awake EEG is normal but clinical suspicion of seizures is present.

Benefits

Identification of seizures. Previously used for identification of brain death, but that use has been largely replaced by other imaging tests.

Harms

Negligible

Frequency/Dose/Duration

Generally only one assessment.

Rationale

Electroencephalography (EEG) has been used for the diagnosis of seizures and coma and seizures that may accompany TBI (Corbin-Berrigan et al., 2020). Sometimes subtle EEG abnormalities has been reportedly helpful among patients who incurred mild and moderate

TBIs (McNerney et al., 2019, Fratantoni et al., 2017, Lai et al., 2020). EEG has been found to show signs of abnormalities among concussed athletes (Cao et al., 2010, Barr et al., 2012, Slobounov et al., 2009). In a low-quality study of patients with severe TBI, EEG findings on admission predicted subsequent epilepsy (Pease et al., 2023). EEG findings have been found to be associated with level of cognitive function over a 3-month period in a low-quality study (Bagnato et al., 2010). Attempts have been made to use EEG monitoring pre-concussion for athletes, although the utility of this approach is somewhat unclear (Abdul Baki et al., 2023). EEG is not invasive, has no adverse effects, is moderate cost, and has utility in the diagnosis and management of seizures related to TBI; thus, it is recommended for evaluation of TBI.

Continuous EEG has been assessed in moderate-quality studies, but while one found utility to capture 50% of seizures among severe ICU patients (Eickholtz et al., 2022), others found changes associated with 3- and 6-month clinical outcomes (Hebb et al., 2007, Lee et al., 2019). Two additional studies found it helpful for ICU patients with moderate to severe TBI (Vespa et al., 2002, Tewarie et al., 2023). However, one study found low-yield among other patients and that the technology was too costly to warrant routine use (Aquino et al., 2017). Thus, while continuous EEG may be indicated for ICU patients, it is not indicated for use in patients with non-severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Electroencephalography OR EEG; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 592 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 592 articles, 30 in CINAHL, 0 in Cochrane Library, 19,000 in Google Scholar, and 0 from other sources†. We considered for inclusion 13 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 9 from other sources. Of the 26 articles considered for inclusion, 23 diagnostic studies and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

QUANTITATIVE ELECTROENCEPHALOGRAPHY (QEEG) FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Quantitative electroencephalograph (QEEG) is not recommended for patients with mild TBI. There is no recommendation for those with moderate to severe acute TBI.

Strength of evidence Not Recommended, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are few moderate-quality studies (Lewine et al., 2019, Kulyk, 2018) and some low-quality studies (Stevens et al., 2024, Haveman et al., 2019, Buhagiar et al., 2023, McNerney et al., 2019, Barr et al., 2012, Slobounov et al., 2009), with some studies suggesting some value of QEEG (which is the quantitative manipulation of an EEG and is dependent on the quality of the EEG being quantitatively manipulated) in the evaluation of patients with mild traumatic brain injury.

QEEG is not invasive, has challenges related to the lack of standardization of interpretations of results, and is moderate cost. QEEG is not recommended for the diagnosis of mild TBI at this point, as there are four important issues that have not been resolved regarding its potential use for mild TBI: (1) definition of a gold standard against which the diagnostic performance of any QEEG modality could be measured, (2) consensus on methods for data acquisition, (3) analysis of multiple QEEG measures representing different neurophysiological aspects, and (4) inclusion of these metrics and use of appropriate statistical methods to develop a predictive, as opposed to merely an explanatory, model (Tenney JR, 2021).

Because quality data do not support use of QEEG in the mild TBI setting, it is not recommended for use among patients with mild TBI. There is no recommendation for use in patients with moderate to severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Quantitative electroencephalography OR qEEG OR Electroencephalography OR EEG; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 604 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 604 articles, 30 in CINAHL, 88 in Cochrane Library, 17,500 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 5 diagnostic studies and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of

100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ELECTROMYOGRAPHY

For recommendations on electromyography (EMG) and nerve conduction studies, see other ACOEM guidelines, such as Hand, Wrist, and Forearm Disorders; Elbow Disorders; and Ankle and Foot Disorders.

ELECTRONEURONOGRAPHY

Electroneuronography (ENoG) is a neurological test that assesses the integrity and ability of the facial nerves. The purpose of ENoG is to quantify the percentage of nerve fibers that can be stimulated [(381)]. ENoG is useful for the evaluation of direct trauma to the face, but it is not diagnostic of traumatic brain injury.

ELECTRONEURONOGRAPHY (ENOG) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Electroneuronography is recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Known or suspected facial nerve injuries, especially when unilateral or asymmetric.

Benefits

Identification and quantification of facial nerve injuries. Occasionally may result in need for surgery to improve the clinical outcome.

Harms

Negligible

Frequency/Dose/Duration

Generally only one assessment.

Rationale

There are no quality studies assessing EnoG for diagnosis of facial nerve injury from TBI, although there are low-quality studies (Remenschneider et al., 2017). EnoG is minimally invasive, has no adverse effects, is moderate cost, and is thought to aid in the identification of facial nerve injury. Thus, it is selectively recommended to identify facial nerve injuries associated with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Electroneuronography OR EnoG; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 14 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 14 articles, 0 in CINAHL, 2 in Cochrane Library, 24,200 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 diagnostic study and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

EVOKED POTENTIALS

Somatosensory evoked potentials have been used to determine if neurological damage has occurred from a traumatic brain injury [382-385]. Electromyography (EMG) measures the health of the muscles and the nerves that control your muscles. This is done by evaluating the electrical activity levels in the muscles while resting and contracting. A nerve conduction study is often part of the EMG evaluation and examines how well nerves are functioning. The speed and velocity of the electrical signals produced by stimulated nerves is recorded [386].

SOMATOSENSORY EVOKED POTENTIAL (SSEP) FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for somatosensory evoked potential (SSEP) for use in the evaluation of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Harms

Negligible

Rationale

There are no quality studies assessing somatosensory evoked potential (SSEP) for the diagnosis and follow-up of TBI, and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Somatosensory Evoked Potential; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 0 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 0 articles, 0 in CINAHL, 0 in Cochrane Library, 16,300 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 diagnostic study and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VESTIBULAR EVOKED MYOGENIC POTENTIALS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Vestibular evoked myogenic potentials are recommended to selectively evaluate patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

The sole quality study included patients with symptoms such as dizziness, persisting for over 10 days and with a diagnosis of post-concussion syndrome (Felipe et al., 2021).

Benefits

Evaluation of vestibulocollic reflexes affected by TBI.

Harms

Negligible.

Rationale

One moderate-quality study suggested utility of assessing vestibular evoked myogenic potentials to evaluate patients with mild TBI (Felipe et al., 2021), as did another low-quality study (Jafarzadeh et al., 2020). Measurement of vestibular evoked myogenic potentials is not invasive, has no adverse effects, is low cost, and has some evidence of suggested utility in evaluating patients with TBI. Therefore, it is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Vestibular Evoked Myogenic Potentials, VEMP; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 9 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 9 articles, 0 in CINAHL, 0 in Cochrane Library, 779 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 3 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

OXYGEN MONITORING

Brain oxygen monitoring has been performed to attempt to monitor and mitigate the effects of cerebral tissue hypoxia [387-399].

OXYGEN MONITORING AND THRESHOLDS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Oxygen monitoring is selectively recommended for patients with severe TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Moderate

Indications

Severe TBI injuries with concerns for brain tissue hypoxia.

Benefits

Potential to alter treatment to reduce brain hypoxia.

Harms

Infections, bleeding, further brain tissue damage

Frequency/Dose/Duration

Early patient monitoring until either there are no episodes of tissue hypoxia, episodes of tissue hypoxia have ceased, and/or tissue hypoxia is thought to not be problematic.

Rationale

Oxygen monitoring and thresholds have been used for the diagnosis of traumatic brain injury (Xie et al., 2017, Shen et al., 2024, De Georgia, 2015). There are quality studies assessing brain oxygen monitoring and thresholds for treatment and monitoring of TBI (van den Brink et al., 2000, Stocchetti et al., 2004, Eriksson et al., 2012, Leal-Noval et al., 2010, van Santbrink et al., 2003, Adamides et al., 2009, Stiefel et al., 2005, Valadka et al., 1998, Bardt et al., 1998, Cormio et al., 1999, Cruz, 1998, Robertson et al., 1995). Brain oxygen monitoring and threshold diagnostic testing is invasive, has adverse effects, and is high cost, but has evidence of clinical efficacy; thus, it is selectively recommended for treatment of severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Oximetry OR pulse oximetry OR oxygen monitoring; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 62 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 62 articles, 2 in CINAHL, 99 in Cochrane Library, 17,300 in Google Scholar, and 0 from other sources†. We considered for inclusion 14 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 18 articles considered for inclusion, 15 diagnostic studies and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

POST-CONCUSSION AND SIDELINE TESTS

Multiple concussion screening tests are typically used on the sidelines of contact sports to screen for concussion injuries [400-407]. These include, but are not limited to, the following: ImPACT, MACE, King-Devick, and SCAT [408-410]. The Rivermead post-concussion symptoms questionnaire is an open-access option as a screener [1002]. Post-concussion and/or sideline testing often consists of a computerized test battery. Tests of brain function are typically included, such as symptoms, attention, memory, processing speed, and reaction time. As with all screening tests, confirmatory testing is required so secure a diagnosis.

Military Acute Concussion Evaluation [411] is a two-part cognitive assessment typically used in military settings to evaluate the extent of neurological damage from a TBI. The first section of the screening requires the patient's medical history and a general physical exam. The second section of the screening applies a Standardized Assessment of Concussion (SAC), which includes a neuropsychological battery to test patient orientation, immediate memory, concentration, and memory recall. MACE is based upon a 30-point scale, where a perfect score is 30 and an abnormal score is anything below 25 [411].

The King-Devick screen has been used to screen for TBI, especially for sports [409, 412-430].

The Sport Concussion Assessment Tool (SCAT) is a screening tool particularly used to evaluate athletes [424, 431]. The SCAT-5's components include symptoms, the Glasgow coma scale, the standardized assessment of concussion (SAC) cognitive assessment, Maddock's score, and an evaluation of balance and coordination. SCAT-5 scores can be summed, but there is no normal score of cutoff point. It has been recommended that the SCAT-5 be compared with a baseline screen and subsequent tests following a TBI [432].

One comparative study found improved predictive value with average constriction velocity, average dilation velocity (ADV), 75% re-dilation time, near point of convergence (NPC) break, King-Devick test time, and Convergence Insufficiency Symptom Survey, while also finding the best predictive values for the ADV (0.82) and NPC (0.74) [223].

IMMEDIATE POST-CONCUSSION ASSESSMENT (IMPACT) FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Immediate Post-Concussion Assessment (ImPACT) is not recommended to screen typical occupational patients with potential TBI.

Strength of evidence Not Recommended, Evidence (C)
Level of confidence Low

Rationale

There are many quality studies assessing ImPACT for screening for TBI (Schatz et al., 2006, Blake et al., 2015, Nelson et al., 2015, Echemendia et al., 2016, Manderino et al., 2018, Ferris et al., 2022, Hannah et al., 2020). However, nearly all data are from adolescent or young adult athletes, raising questions about the applicability to occupational settings. A

comparative study found Vestibular/Ocular-Motor Screening and SCAT3 to outperform ImPACT (Ferris et al., 2022). A moderate-quality study concluded the test's high specificity is accompanied by low sensitivity, and the test may under identify poor effort in athletes (Manderino et al., 2018). Another study also found unacceptable sensitivity and specificity values (Czerniak et al., 2023).

While the body of evidence suggests some utility for this tool, the test's overall sensitivity and specificity appear unacceptably low. Sensitivity tends to be higher with batteries of tests used and overall sensitivity estimates range from approximately 40-85%. However, there are some data suggesting prognostic value of IMPACT in severe TBI (Han et al., 2014, Liedes et al., 2015, Honeybul et al., 2016, Castaño-Leon et al., 2016). The ImPACT (current version ImPACT-4) diagnostic test is not invasive, has no adverse effects, and is low cost, but has data suggesting low test performance and that other tests outperform ImPACT, . Therefore, it is not recommended for use as a screening test in typical occupational populations.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Immediate Post-Concussion Assessment and Cognitive Testing, ImPACT; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 3502 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 3502 articles, 198 in CINAHL, 651 in Cochrane Library, 9570 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 2 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 7 diagnostic studies and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MILITARY ACUTE CONCUSSION EVALUATION (MACE) FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of Military Acute Concussion Evaluation (MACE) in the evaluation of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies assessing MACE for diagnosis of TBI in civilian occupational populations. Two moderate-quality studies show some utility of the MACE in military populations with some ability to discriminate TBI from non-TBI (McCrea et al., 2014, Stone Jr et al., 2015). However, the discriminatory ability was deemed to be too poor to administer in civilian populations (Stone Jr et al., 2015). Another moderate-quality study found the DANA Brief Cognitive Test to correlate with the MACE Cognitive Score but without the limitations of the MACE, including portability, durability, test time and not requiring a medical professional to administer (Pryweller et al., 2020). A 2-week test-retest study among hockey players found significant intra- and inter-individual scores including among those without injuries (Hänninen et al., 2021). The MACE diagnostic test is not invasive, has no adverse effects, and is low cost. However, it has no documented evidence of diagnostic efficacy in typical employed populations. Publications have raised questions about its discriminatory ability among civilians, as well as high intra- and inter-individual variance. Thus, there is no recommendation regarding the use of MACE (the current version is 2) in occupational populations for the evaluation of TBI. As some occupational TBI cases have similar ballistics as many military TBI cases, the applicability of the test to select patients may still be reasonable, although that needs to be determined in quality studies.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Military Acute Concussion Evaluation OR MACE; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 18 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 18 articles, 5 in CINAHL, 13 in Cochrane Library, 10,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 3 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

KING-DEVICK SCREENING FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

King-Devick (KD) screening is recommended for selective use in the evaluation of patients with a known baseline.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients with mild, moderate, or severe TBI or athletes. Generally used only among those with a known baseline measurement. King-Devick is a visual performance test used most often in contact sport athletes to quickly detect findings consistent with concussion. Concussion is frequently associated with saccade abnormalities, pursuit eye movement, convergence, accommodation and vestibular-ocular reflex. The King-Devick Test involves having the individual rapidly read the numbers on 3 test cards with the score being the total time required in seconds (Ventura et al., 2014).

Benefits

Simple test that can be implemented with minimal training including among non-medically trained and can be performed rapidly at the sideline. Helps assess degree of TBI.

Harms

Negligible. The test results vary based on multiple factors, e.g., those impacting reading skill level, presence of learning disorders and native language other than English (Chrisman et al., 2019). Thus, results are measured and interpreted as pre/post TBI scores (i.e., the change from baseline), requiring a baseline. Results may also be confounded by intervening depression, medication and any other factor slowing cognitive function (Subotic et al., 2017). Learning effects may also occur and confound by memorization, potentially hiding effects of TBI, although in larger samples this effect appears relatively minor (Breedlove et al., 2019, Nguyen et al., 2020).

Frequency/Dose/Duration

Baseline evaluation. Then measured after subsequent potential TBI event(s). Testing may be performed by non-medically trained individuals.

Rationale

Nearly the entirety of the body of evidence is among athletes in contact sports. A high-quality study suggested that the King-Devick (KD) tool discriminates between concussed and nonconcussed individuals; however, there was no demonstrated superiority over SCAT-5 (Echemendia et al., 2022). There are several moderate-quality studies mostly suggesting KD screening was effective for diagnosis of concussion (King et al., 2015, Galetta et al., 2011, Galetta et al., 2013, Leong et al., 2015, Alsalaheen et al., 2016, Fischer et al., 2016, King et al., 2014, Seidman et al., 2015) (Benedict et al., 2015, Munce et al., 2014, Ventura et al., 2015, Silverberg et al., 2014, Tjarks et al., 2013) (Breedlove et al., 2019, Clugston et al.,

2019, Elbin et al., 2021, Le et al., 2023, Naidu et al., 2018, Walsh et al., 2016); however, most data are from adolescent or young adult athletes, raising questions about the applicability to occupational settings.

One moderate-quality study of military TBI events found the test helpful despite the lack of a KD baseline (Walsh et al., 2016), raising implications about potential applicability of KD beyond athletes. One moderate-quality study found a baseline association between KD results and cognitive measures, concentration, visual motor speed and reaction time, while finding lack of association between KD test results and symptoms, balance and vestibular-oculomotor provocation (Clugston et al., 2019). There are many low quality studies typically among smaller groups and mostly showing similar findings (Rizzo et al., 2016, Subotic et al., 2017, Richard et al., 2022, Onge et al., 2019, Nguyen et al., 2020, Lawrence et al., 2019, King et al., 2024, Krause et al., 2022, King et al., 2020, Hecimovich et al., 2019, Hecimovich et al., 2022, Hood et al., 2019, Gold et al., 2021, Gunasekaran et al., 2020, Cosgrave et al., 2023, Chrisman et al., 2019, Bernstein et al., 2015, Dickson et al., 2019, Whelan et al., 2022). There also is some evidence of persistence of these findings in chronic TBI (Rizzo et al., 2016).

While the body of evidence suggests some utility for KD, the studies somewhat conflict regarding the overall sensitivity of KD and a meta-analysis showed combined estimates of 77% sensitivity and 82% specificity (Harris et al., 2022). Attempts to improve sensitivity by adding an additional test naturally resulted in markedly lower specificity (Fuller et al., 2019), yet multiple authors have suggested adding a second test (Fuller et al., 2019, Naidu et al., 2018), while mostly failing to note the problems of impaired specificity with such a recommendation. Time to re-measure the KD after a potential TBI event has also been found to be greatest at 0-6 hours after the event (Le et al., 2023). The requirement for a baseline measurement is a significant limiting factor for application of KD screening among other, non-athletic, occupational populations, and the current evidence base is sparse for its potential use without a baseline. That a high-quality study showed no benefit over using the SCAT-5 (Echemendia et al., 2022) suggests it may have limited value.

The KD test is not invasive, has no adverse effects, is low cost, and has moderate evidence suggesting some limited diagnostic screening utility. Thus, it is recommended for selective evaluation of patients with potential TBI. As of the latest comprehensive update of this guideline, the current version is King-Devick 5.5; when an updated version of the tool is available, it is recommended to use that version).

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: King Devick OR KDt; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 151 article in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 151 article, 28 in CINAHL, 13 in Cochrane Library, 1,320 in Google Scholar, and 0 from other sources†. We considered for inclusion 20 from PubMed, 2 from CINAHL, 0 from Cochrane Library, 7 from Google Scholar, and 0

from other sources. Of the 29 articles considered for inclusion, 27 diagnostic studies and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SPORT CONCUSSION ASSESSMENT TOOL (SCAT) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

The Sport Concussion Assessment Tool (SCAT) is recommended to screen patients with possible TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

The SCAT is a screening evaluative tool and not a diagnostic tool. Use may possibly include both post-TBI testing and repeat testing to follow progress. While developed for sports settings, it has been successfully implemented in emergency departments (Bin Zahid et al., 2018).

Benefits

Identification of severity of concussion, follow-up of symptoms and at resolution of symptoms.

Harms

Negligible. Potential for occasional misinterpretations especially where baseline data are missing.

Frequency/Dose/Duration

Administered to screen for TBI and monitored periodically during recovery. For high risk situations, baseline or pre-concussion testing may help measure the baseline (Sahler et al., 2012). Baseline, pre-TBI testing would rarely be indicated in occupational settings.

Rationale

SCAT has been used for the diagnosis of traumatic brain injury (Echemendia et al., 2023). The current version is SCAT-6, however, prior versions have been evaluated in quality

studies. One high-quality study suggests the Sport Concussion Assessment Tool (SCAT-5) was discriminatory as a screening test between non/concussed individuals and that the King-Devick tool did not show superiority to SCAT-5 (Echemendia et al., 2022). There are many moderate-quality studies suggesting SCAT is useful for screening for TBI, particularly within the first 72 hours of injury (Benedict et al., 2015, Luoto et al., 2014, Snyder et al., 2014, Bruce et al., 2021, Garcia et al., 2020, Bin Zahid et al., 2018, Caccese et al., 2023, Downey et al., 2018, Fuller et al., 2020, Fuller et al., 2021, Ferris et al., 2021). One comparative study suggested the SCAT-2 is superior to the MACE (Luoto et al., 2014). A comparative study found Vestibular/Ocular-Motor Screening and SCAT3 to out perform ImPACT (Ferris et al., 2022). One study suggested utility of SCAT, although it also found differences by age and gender, potentially rendering interpretations more challenging (Benedict et al., 2015). A history of psychiatric illness was noted to potentially confound interpretation in a low-quality study (Coscia et al., 2021). A moderate-quality study found utility for emergency department applications (Bin Zahid et al., 2018). However, a low-quality study found challenges administering SCAT in an emergency department because of length and interruptions (Sik et al., 2023). The SCAT diagnostic test is not invasive has no adverse effects, is low cost, has some evidence of efficacy as a screening test, and is recommended for evaluation and follow-up of possible TBI. As of the latest comprehensive update of this guideline, the current version of the SCAT is SCAT-6; when an updated version of the tool is available, it is recommended to use that version.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Sports Assessment Concussion Tool, SCAT; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 337 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 337 articles, 9 in CINAHL, 6 in Cochrane Library, 2490 in Google Scholar, and 0 from other sources†. We considered for inclusion 13 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 17 articles considered for inclusion, 16 diagnostic studies and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

PSYCHOLOGICAL AND PERSONALITY ASSESSMENTS

INTELLIGENCE TESTS

Intelligence testing has been widely used to assist in comprehensive neuropsychological evaluations, including those of persons with traumatic brain injury [433]. One of the more commonly used intelligence tests is the Wechsler Adult Intelligence Scale (WAIS, now WAIS-5) [434, 435, 436], having been commonly used [437] for estimating full scale IQ score (FSIQ) among patients with TBI also to aid in the identification of feigning and/or exaggeration [435, 438-450].

Automated Neuropsychological Assessment Metrics [367] is a computerized neuropsychological battery that has been primarily used in military settings [451-460]. This assessment includes six tests, including: Simple Reaction Time (SRT), Continuous Performance Test (CPT), Sternberg Memory [461], Mathematical Processing (MTH), Matching to Sample (MSP), Code Substitution-Delayed (CDD), and Spatial Processing (SPD) [455].

WECHSLER ADULT INTELLIGENCE SCALE FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

The Wechsler Adult Intelligence Scale (WAIS) is moderately recommended for use in the evaluation of patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence High

Indications

Post-TBI testing. Repeat testing to follow progress may be sometimes helpful.

Benefits

Identification of severity of TBI, follow-up of symptoms and at resolution of symptoms. May assist with identification of feigning (Reid-Arndt et al., 2011, Miller et al., 2004, Greve et al., 2002, Greve et al., 2008, Mathias et al., 2002, Wilbur et al., 2008, Walker et al., 2009, Strong et al., 2005, Curtis et al., 2009). The WAIS is often used in conjunction with clinical picture as well as Wechsler Memory Scale IV to attempt to substantiate subjective complaints.

Harms

Negligible. Potential for occasional misinterpretations, especially where baseline data are missing.

Frequency/Dose/Duration

Administered after TBI to assist with patient management.

Rationale

There are several moderate-quality studies suggesting utility of WAIS and/or WAIS-IV for evaluation of patients who sustained TBI (Reid-Arndt et al., 2011, Miller et al., 2004, Greve et al., 2002, Greve et al., 2008, Mathias et al., 2002, Wilbur et al., 2008, Walker et al., 2009,

Strong et al., 2005, Curtis et al., 2009, Lida, 2020, Erdodi, 2020). WAIS is not invasive, has no adverse effects, is of moderate cost, has evidence of accuracy for assessing IQ and for detecting feigning, and is thus recommended for evaluation of patients with TBI. The test is periodically updated and the most recent version is recommended. As of the latest comprehensive update of this guideline, the current version of the WAIS is WAIS-V; when an updated version of the tool is available, it is recommended to use that version.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Weschler Adult Intelligence Scale, WAIS, WAIS-III; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 39 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 39 articles, 1 in CINAHL, 13 in Cochrane Library, 9,500 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 3from Google Scholar, and 0 from other sources. Of the 3articles considered for inclusion, 3 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MEMORY, FEIGNING, EXAGGERATION, AND POOR EFFORT TESTS

Memory tests have been used to assess patients with TBI [440, 462-475]. There are many different types of memory tests used, including: Everyday Memory Questionnaire (EMQ), Spatial Recall Test [467] Short Orientation Memory and Concentration Test (SOMC) [464], Recognition Memory Tests (RMT) [468], the Wechsler Memory Scale (WMS), standardized assessment of concussion (SAC), Montreal Cognitive Assessment (MOCA), as well as many others.

Tests to detect feigning, and sometimes used to infer malingering, have been used to assess patients with TBI (see the ACOEM Mental Health Introduction) [434, 435, 437, 438, 476, 477]. In addition to tests specifically designed to assess effort and feigning, there are standardized tests of neuropsychological functioning that have been shown to demonstrate the ability to detect suboptimal effort, although they are not malingering tests per se. These are commonly referred to as “embedded measures” of malingering. There are various different types of feigning tests used, including: the Test of Memory Malingering (TOMM) [437, 472], Word Memory Test (WMT) [476], the Portland Digit Recognition Test [215], Reliable Digit Span test [463], the Wisconsin Card Sorting test [438], as well as others. Effort testing (symptom validity and performance validity) should be an expected part of all cognitive assessments

following TBI, especially in a medicolegal context, including work-related injuries subject to a claims process.

Wechsler Memory Scale (WMS) has been used to assess memory impairments which may occur with moderate and especially severe TBI, although mild traumatic brain injury (MTBI) typically does not result in significant and persistent memory impairment [170, 478, 479, 480]. When substantial memory dysfunction is present, as indicated on the WMS [434], other factors not related to trauma-induced neuropathology should be considered, such as pre-existing problems, psychological issues, or lack of motivation (effort) during testing [481].

Multiple tests have been used to correctly identify TBI injury severity resulting in cognitive dysfunction versus insufficient effort or feigning and or symptom exaggeration [164]. Poor effort has been proven to significantly impact post-concussion symptoms as well as test performance [156, 482, 483, 484, 485]. The TOMM evaluates validity of the test performance that is being used to establish the presence or absence of neurocognitive dysfunction associated with TBI.

Following a mild TBI, up to 15% of patients report having cognitive problems including memory deficits, reduced information processing speed, concentration problems, etc. [303, 486]. Some general measurements of cognitive function, including intelligence tests have been suggested to be insufficient. Therefore, cognitive event-related potential latency has been proposed as a more reliable diagnostic measure for cognitive impairment following TBI [487].

MEMORY AND FEIGNING TESTS FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Memory and feigning tests are recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Patients with moderate or severe TBI experiencing cognitive difficulties. May be performed to help guide treatment. May later be performed as part of an evaluation for end-of-healing and clinical plateau. Generally not used for patients with mild TBI; however, highly selective use among those with either high and critical occupational cognitive demands and/or memory complaints may also be indicated.

Benefits

Memory tests used to identify and measure memory difficulties, potentially allowing better tailoring of therapies to address any memory deficits. Tests suggesting feigning are sometimes used to identify and measure intentional production of exaggerated or false symptoms, and sometimes are used to infer, although do not by themselves prove malingering.

Harms

Negligible in most patients. Memory testing is strongly subject to feigning and many comparative studies exclude all patients involved in any litigation. Thus, careful interpretation and potential pairing with tests for feigning are indicated especially where there is strong potential for secondary gain(s).

Frequency/Dose/Duration

Generally not performed more than once or twice. May be used to target specific cognitive rehabilitation strategies. Memory tests may later help determine end of healing and extent of residual deficits, if any.

Rationale

There are quality studies assessing memory tests for diagnosis of TBI (Gates et al., 2023, Kanser et al., 2019). There are also quality studies assessing feigning tests for for evaluation of patients with TBI. However, there are few comparative trials of sufficient size and rigor to allow a recommendation of one type of testing over another. Memory and feigning tests are not invasive, have no adverse effects, are low cost, have evidence of diagnostic efficacy, and are thus recommended for diagnosis and evaluation of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Memory and Learning Tests OR memory malingering OR TOMM; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 41 article in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 41 article, 5 in CINAHL, 8 in Cochrane Library, 4,570 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 2 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CALIFORNIA VERBAL LEARNING TEST (CVLT) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

The California Verbal Learning Test (CVLT-3) is recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Generally used in patients with mild TBI, particularly for evaluating learning, memory and feigning.

Benefits

Assess memory and learning. Identification of feigning.

Harms

Negligible

Frequency/Dose/Duration

Generally used on one occasion if use is for detecting feigning. May be used on subsequent occasions to track learning and memory progress.

Rationale

The two highest quality studies suggest CVLT-II is useful for evaluating memory and feigning (Curtis et al., 2006, Greve et al., 2009, Persinger et al., 2018, Woods et al., 2017, Leitner et al., 2019, Martin et al., 2023). One moderate-quality study suggests CVLT-II is more sensitive for memory measures than the Word Memory Test (Davis, 2016). The current version is CVLT-3. CVLT-3 is not invasive, has negligible adverse effects, is low cost, and is recommended for evaluation of patients with TBI. As of the latest comprehensive update of this guideline, the current version of the CVLT is CVLT-3; when an updated version of the tool is available, it is recommended to use that version.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: California Verbal Learning Test OR CVLT; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 27 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 27 articles, 1 in CINAHL, 15 in Cochrane Library, 17,200 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from

Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 3 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

REPEATABLE BATTERY OF THE ASSESSMENT OF NEUROPSYCHOLOGICAL STATUS (RBANS) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

The Repeatable Battery of the Assessment of Neuropsychological Status (RBANS) is recommended for use as a screening test in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients with ongoing cognitive symptoms from TBI as a screening test. May also be used to assess effort and feigning (Lippa et al., 2017, Novitski et al., 2012).

Benefits

Assess cognitive function in five domains. Feigning is potentially able to be evaluated with two subscales (Lippa et al., 2017).

Harms

Negligible

Frequency/Dose/Duration

Generally used on one occasion if use is for detecting feigning. May be used on subsequent occasions to track learning and memory progress.

Rationale

The highest-quality studies suggest that RBANS is useful as a screening test for evaluating cognitive function (McKay et al., 2008, Lippa et al., 2013) and feigning (Lippa et al., 2017, Novitski et al., 2012). RBANS is not invasive, has negligible adverse effects, is low cost, and is recommended as a screening test for evaluation of patients with TBI. As of the latest

comprehensive update of this guideline, the current version of the RBANS Update; when an updated version of the tool is available, it is recommended to use that version.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Repeatable Battery for the Assessment of Neuropsychological Status OR RBANS; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 20 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 20 articles, 1 in CINAHL, 5 in Cochrane Library, 7,950 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 2 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

WECHSLER MEMORY SCALE FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

The Wechsler Memory Scale is moderately recommended for use in the evaluation of patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

Assess memory after TBI. May be used in select cases of mild TBI with ongoing symptoms. Repeat testing to follow progress may sometimes be helpful. May help evaluate potential symptoms exaggeration and feigning.

Benefits

Identification of severity of TBI, follow-up of symptoms and at resolution of symptoms. May assist with identification of feigning. Often used in conjunction with WAIS-III as well as the clinical picture to attempt to substantiate subjective complaints (West et al., 2011, Ord et

al., 2008, Glassmire et al., 2003, Hacker et al., 2009, Langeluddecke et al., 2005, Hawkins, 1998).

Harms

Negligible. Potential for occasional misinterpretations especially where baseline data are missing.

Frequency/Dose/Duration

Administered after TBI, often at the point of maximum recovery.

Rationale

Multiple moderate-quality studies suggest utility of WMS-III for evaluation of patients who sustained TBI (Iverson, 2005, Belanger et al., 2005, Carroll et al., 2004, Schretlen et al., 2003). The WMS-III is not invasive, has no adverse effects, is moderate cost, has evidence of utility for memory assessment, and is thus recommended for evaluation of patients with TBI. The test is periodically updated and the most recent version is recommended. As of the latest comprehensive update of this guideline, the current version of the WMS is WMS-IV; when an updated version of the tool is available, it is recommended to use that version.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Wechsler Memory Scale–Third Edition, Wechsler Memory Scale-III, WMS-III; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 0 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 0 articles, 0 in CINAHL, 0 in Cochrane Library, 1110 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

TEST OF MEMORY MALINGERING (TOMM) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

The Test of Memory Malingering (TOMM) is a performance validity test and is moderately recommended for use in the evaluation of patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence High

Indications

Post-TBI testing. Indicated for all mild TBI cases being seen for psychometric testing, and may be helpful among select moderate or severe TBI cases. (Gervais et al., 2004, Paniak et al., 2002, Guise, 2010, Hall et al., 2014, Binder et al., 1997, Cook, 1972, Miller, 1961, Teichner et al., 2004, Schroeder et al., 2013, Ashendorf et al., 2004, Constantinou et al., 2005, Kirkwood, 2015, Lange et al., 2015, Haber et al., 2006, Whitney, 2013, Heyanka et al., 2015, Bashem et al., 2014).

Benefits

Identification of severity of TBI. May assist with identification of feigning and to attempt to substantiate subjective complaints.

Harms

Negligible

Frequency/Dose/Duration

Administered after TBI, generally early in the clinical course.

Rationale

There are several moderate-quality studies assessing TOMM evaluation of patients who sustained TBI (Hall et al., 2014, Whitney, 2013, Barhon et al., 2015, Lange et al., 2010, Flaherty et al., 2015, Schroeder et al., 2013, Guise, 2010, Teichner et al., 2004, Haber et al., 2006, Bashem et al., 2014, Ashendorf et al., 2004, Constantinou et al., 2005, Stenclik et al., 2013). This test is not invasive, has no adverse effects, is of moderate cost, has evidence of accuracy (especially for detecting feigning among patients with mTBI), and is thus recommended. It is excellent for the evaluation of patients with TBI who are undergoing psychometric testing, but is not useful for tracking progress. As of the latest comprehensive update of this guideline, the current version of the TOMM is TOMM-2; when an updated version of the tool is available, it is recommended to use that version.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Test of memory malingering OR TOMM; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 31 article in PubMed using Most Recent tab, and we did

a secondary search in PubMed using Best Match tab to find and review 31 article, 5 in CINAHL, 8 in Cochrane Library, 4710 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COGNITIVE EVENT-RELATED POTENTIAL FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Cognitive event-related potential has been recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients in the acute TBI phase who have symptoms of cognitive deficits.

Benefits

Identification of cognitive deficits that may potentially be addressed by further cognitive therapy.

Harms

Negligible

Frequency/Dose/Duration

Baseline evaluation. May be used to evaluate progress and/or residual cognitive deficits.

Indications for discontinuation

Sufficient recovery, plateau, end of healing.

Rationale

There are a few quality studies assessing cognitive event-related potential for diagnosis of cognitive impacts of TBI and suggesting utility in the acute-care phase (Gosselin et al., 2012, Soldatovic-Stajic et al., 2014, Candrian et al., 2018, Ledwidge et al., 2016, Chen et al., 2021).

Cognitive event-related potential is not invasive, has no adverse effects, is low cost, has evidence of diagnostic efficacy, and is recommended for diagnosis of cognitive impacts of TBI in the acute phase to identify residual cognitive capacity.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Cognitive event related potential; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 64 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 64 articles, 1 in CINAHL, 189 in Cochrane Library, 18,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 6 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 6 diagnostic studies and 0 systematic reviews met the inclusion criteria.
† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

NEUROPSYCHOLOGICAL ASSESSMENTS

Neuropsychology is a specialized branch of psychology involving the assessment, management and rehabilitation of people suffering illness or disease (particularly to the brain). Neuropsychologists evaluate symptoms and neurocognitive (dys)function. Patient injuries and disorders evaluated include, but are not limited to TBI. Other disorders evaluated and treated by neuropsychologists include neurodegenerative disorders, multiple sclerosis, strokes, neurodevelopmental conditions, etc.

Neurocognitive dysfunction may be reflected in personality, intelligence, attention, executive function, reasoning, problem solving, information processing, and memory. Cognitive testing generally consists of a comprehensive evaluation of the patient's cognitive status by specific neurologic domains. Various testing batteries have been used, including for the evaluation of patients with TBI [401, 402, 488, 489]. Neuropsychological assessments frequently include analyses of effort and signs of exaggeration.

Neuropsychology occupies a prominent role in the evaluation and treatment of patients with TBI, especially moderate and severe patients. In most cases, mild TBI resolves within a few days and thus there is little role for professional evaluation(s) and treatment(s) other than natural recovery. However, neuropsychology is also highly helpful in the evaluation of patients with mild TBI with persistent symptoms beyond 1 month. Neuropsychology employs assessments that frequently consist of a thorough clinical and neuropsychological assessment of TBI and various types of tests and test batteries to identify abnormalities

related to TBI [72, 211, 213, 303, 490, 491]. These tests typically undergo frequent revisions and the most up-to-date version of the tests should be administered.

Normally, patients are given a battery of tests in numerous different domains (e.g., intelligence, memory, executive function, speech, language, visual spatial) to assess impacts of, and plan treatment of, patients with TBI. The National Institute of Neurological Disorders and Stroke have a a toolbox that includes helpful information [492-500]. Some of these tests are referred to below according to specific cognitive domains (e.g., intelligence, attention and concentration, memory). It should also be noted that this review is not intended to be all inclusive. Many tests and test batteries are not included in this review, as there are hundreds of various tests of neuropsychological and cognitive functioning. Additional tests may be included for review in subsequent revisions. Neuropsychological rehabilitation for TBI may consist of psychotherapy, cognitive exercises, and retraining. Neuropsychological tests and treatments are reviewed individually by topic in later sections.

NEUROPSYCHOLOGICAL AND NEUROCOGNITIVE ASSESSMENT FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Neuropsychological assessment is recommended for the evaluation and treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence High

Indications

Patients with moderate or severe TBI experiencing cognitive difficulties. Patients with mild TBI with ongoing symptoms are also candidates for neuropsychological assessments, although most mild cases are expected to rapidly resolve and not require evaluation. May be performed to help guide treatment, oversee psychological and cognitive-related treatments and may later be performed as part of an evaluation for end-of-healing and clinical plateau. Well-performed neuropsychological evaluations are widely considered indispensable for evaluation of TBI impairments (Williams et al., 2013).

Benefits

Identify and measure psychological, neuropsychological, social, behavioral and cognitive capabilities, potentially allowing better tailoring of therapies to address the specific deficits.

Harms

Negligible

Frequency/Dose/Duration

Generally, a comprehensive assessment with a battery of tests is performed once or twice assessing numerous different domains (e.g., intelligence, memory, executive function,

speech, language, visual spatial). Ongoing focused assessments and treatments are then provided targeting deficits or functional issues identified in the assessment. Some patients may benefit from additional assessments to track progress. May be used to target specific rehabilitation strategies. May later help determine end of healing and extent of residual deficits, if any.

Rationale

Neurocognitive testing and neurocognitive assessment have been used for the diagnosis of traumatic brain injury (Egeto et al., 2019). Several moderate-quality studies of neurocognitive testing show differences between non/concussed individuals (Covassin et al., 2008, Panwar et al., 2019, Ponsford et al., 2012, Wickwire et al., 2023, Lunter et al., 2019). Neuropsychological assessments are not invasive, have no adverse effects, are moderately costly, are thought to be effective for evaluation of patients with TBI, and are thus recommended for the evaluation of patients with TBI. The most recent version of the test should be used.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Neurocognitive testing OR neurocognitive assessment; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 545 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 545 articles, 15 in CINAHL, 54 in Cochrane Library, 20,200 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 3 diagnostic studies and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

AUTOMATED NEUROPSYCHOLOGICAL ASSESSMENT METRICS (ANAM) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Automated Neuropsychological Assessment Metrics (ANAM) is recommended for evaluation of patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

Post-TBI testing, although this tool has also been used with baseline assessments in a pre-injury military population (Haran et al., 2016). Not used for diagnostic purposes, but is used as a test of neurocognitive functioning to help provide support to confirm or disconfirm the presence of mild TBI symptoms. Repeat testing to follow progress may also be helpful (Norris et al., 2013).

Benefits

Follow-up of symptoms and at resolution of symptoms, although test re-test reliability may be concerning.

Harms

Negligible. Potential for occasional misinterpretations especially where baseline data are missing.

Frequency/Dose/Duration

Administered after concussion and monitored periodically during recovery. For high risk situations, baseline or pre-concussion testing may help measure the baseline. Baseline, pre-concussion testing would rarely be indicated in occupational settings.

Rationale

There are many moderate-quality studies reporting utility of ANAM for screening for TBI (Bryan et al., 2012, Norris et al., 2013, Luethcke et al., 2011, Cernich et al., 2007, Kelly et al., 2012, Vincent et al., 2012, Norris et al., 2014, Vincent et al., 2008, Betthauser et al., 2018, Cole et al., 2018, Dretsch et al., 2015, Glutting et al., 2021, Iverson et al., 2020, Mabry, 2021, Meyers et al., 2022, Sours et al., 2015, Porter et al., 2020). All studies suggest utility of ANAM for diagnosis and/or prognosis and populations assessed include sports, military and others. One study reported recovery time in a military population was able to be estimated by ANAM (Porter et al., 2020). One study evaluating ANAM, DANA, and ImPACT reported symptoms scores outperformed the computerized tests (Nelson et al., 2017). The ANAM test is not invasive, has no adverse effects, is low cost, has evidence of efficacy, and is recommended for evaluation of TBI. As of the latest comprehensive update of this guideline, the current version of the ANAM is ANAM4; when an updated version of the tool is available, it is recommended to use that version.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms:

automated neuropsychological assessment metrics OR ANAM; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 36 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 36 articles, 4 in CINAHL, 6 in Cochrane Library, 8,540 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 7 from Google Scholar, and 0 from other sources. Of the 11 article considered for inclusion, 11 diagnostic study and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

PERSONALITY ASSESSMENTS

The MMPI-2 (also MMPI-2-RF and MMPI-3) has been widely used to assist in comprehensive psychological evaluations, including those of persons with traumatic brain injury [501, 502, 503, 504, 505, 506]. Its use has been reported among patients with TBI, including for the identification of feigning and/or exaggeration, and is particularly helpful among those who continue to be symptomatic for extended periods of time.

MINNESOTA MULTIPHASIC PERSONALITY INVENTORY (MMPI) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

The Minnesota Multiphasic Personality Inventory (MMPI) is recommended for use in the evaluation of patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

Post-TBI testing among those who remain symptomatic for extended periods of time. Repeat testing to follow progress may sometimes be helpful. There may be limited indications in patients with mild TBI.

Benefits

Measure of psychological and emotional factors, including developing support for a psychiatric disorder (e.g., somatic symptom disorder, major depressive disorder) or identify maladaptive personality characteristics that may better account for an individual's symptom

complaints. May assist with identification of over-reporting of symptoms as well as feigning (Lange et al., 2015, Jones, 2016, Pape et al., 2016, Lange et al., 2015, Bolinger et al., 2013, Goodwin et al., 2013, Peck et al., 2013) (Willmott C, 2009, Whitney, 2013). Often used in conjunction with clinical picture to attempt to substantiate subjective complaints.

Harms

Negligible. Potential for occasional misinterpretations especially where baseline data are missing.

Frequency/Dose/Duration

May be administered to assist with identification of psychological and emotional factors.

Rationale

There are many moderate-quality studies assessing MMPI for evaluation of patients who sustained TBI (LaChapelle DL, 2005, Manderino et al., 2018, Greve et al., 2006, Alkemade et al., 2015, Alkemade et al., 2019, Gass et al., 2017, Goldsworthy et al., 2019, Gradwohl et al., 2020, Jurick et al., 2019, Guzowski et al., 2022, Jones, 2016, Whitney, 2013, Arbisi et al., 2011, Peck et al., 2013, McCusker PJ, 2003, Larrabee, 2003, Nelson et al., 2011, Youngjohn et al., 1997, Youngjohn et al., 2011, Van Dyke et al., 2013, Bolinger et al., 2014, Kim et al., 2013, Thomas et al., 2009). MMPI testing has been found to be helpful for identification of somatic complaints (Guzowski et al., 2022, Gass et al., 2017), premorbid factors (Goldsworthy et al., 2019), compromised insight (Gass et al., 2017), and issues of self-perception (Gass et al., 2017). One moderate-quality study identified possible symptom exaggeration among 50-87% of 46 veterans seeking compensation (Jurick et al., 2019). The MMPI is not invasive, has no adverse effects, is moderate cost, has evidence of accuracy especially for detecting feigning, and is thus recommended for evaluation of patients with TBI. As of the latest comprehensive update of this guideline, the current version of the MMPI is MMPI-3; when an updated version of the tool is available, it is recommended to use that version.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Minnesota Multiphasic Personality Inventory, MMPI; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 20 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 20 articles, 1 in CINAHL, 0 in Cochrane Library, 2450 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 6 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SWALLOW STUDIES

Swallowing impairment (dysphagia) is common in some patients with severe TBI due to prolonged intubation or tracheostomy, the traumatic injury itself, medications or weakened swallowing muscles due to lack of use [507, 508, 509]. These patients may require testing to determine swallow function, extent of dysfunction, and adequacy of airway protection. There are several different types of swallow studies, including bedside clinical assessment, the modified Evans Blue-Dye Test (MEBDT), and instrumental evaluations such as barium swallow, modified barium swallow (MBS) fiberoptic endoscopy (FEES), fiberoptic endoscopic evaluation with sensory testing (FEEST) and videofluoroscopic studies, which add oropharyngeal pressure assessment (MSE). Although there are many different tests, they all evaluate the ability of the patient to swallow. The threshold for evaluating swallow studies is low among those with prolonged intubation, tracheostomy, difficulty swallowing, or signs of gagging or aspiration.

VESTIBULAR FUNCTION AND BALANCE TESTS

Following a mild traumatic brain injury, up to 30% of patients report having balance disorders including dizziness, impaired balance, and reduced coordination [510]. Typically, clinicians diagnose balance impairment following TBI using subjective measures. However, some objective measures may suggest, but not diagnose, TBI, including computerized dynamic posturography platforms [511].

Vestibular function testing is used to quantify and assess the status of an individual's vestibular system [512]. Vestibular function testing has been used to help define the severity and possible outcomes of an individual's dizziness and balancing issues [512]. Testing includes specific tests such as electro- or video-nystagmography (ENG/VNG), rotary chair testing, computerized dynamic platform posturography, electrocochleography (ECoG), and vestibular evoked myogenic potentials (VEMP) [513].

Videonystagmography is a useful laboratory tool used for assessing balance function in individuals who have suffered from TBI. It tests the functional capabilities of the vestibular system, studying eye movement behavior of the patient [514]. Rotary chair testing is used to diagnose vestibular impacts of traumatic brain injuries. Rotary chair testing examines vestibular and oculomotor functioning [515]. Electronystagmogram (ENG) is a diagnostic test that measures involuntary eye movements and is typically used as part of an assessment of balance problems and dizziness [516].

VESTIBULAR FUNCTION TESTING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Vestibular function testing is recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Equivocal results of a medical history and/or questionnaire(s) regarding vestibular symptoms.

Benefits

Ability to better define extent of vestibular problems.

Harms

Negligible.

Frequency/Dose/Duration

May be used at baseline. One or two follow-up assessments are reasonable to define progress.

Indications for discontinuation

Resolution of vertiginous symptoms, improvement sufficient to not need further rehabilitation.

Rationale

There are few quality studies assessing tests of vestibular function for diagnosis of impacts of TBI (Gottshall et al., 2010, Ferris et al., 2022, Akin et al., 2022). There are no studies showing testing is superior to a medical history or questionnaires. There are reports of vestibular dysfunction in patients with TBI (Guise, 2010, Gottshall et al., 2010, Ferris et al., 2022, Akin et al., 2022). Vestibular function tests are not invasive, have few adverse effects, are low cost, have limited evidence of efficacy, and are selectively recommended for use in patients with unclear results from a medical history and/or questionnaires.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Vestibular Function Testing, Vestibular Testing, VFT**;** traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 15 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 15 articles, 1 in CINAHL, 0 in Cochrane Library, 1050 in Google Scholar, and 0 from

other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 diagnostic study and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMPUTERIZED DYNAMIC PLATFORM POSTUROGRAPHY FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of computerized dynamic platform posturography in the evaluation of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies assessing computerized dynamic platform posturography for the evaluation of TBI. It is not invasive, has no adverse effects, and is low cost. However, without quality evidence of diagnostic efficacy, there is no recommendation for the evaluation of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: computerized dynamic platform posturography, CDP, computerized dynamic posturography; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 18 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 18 articles, 18 in CINAHL, 0 in Cochrane Library, 706 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 2 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are

reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ELECTRONYSTAGMOGRAPHY OR VIDEONYSTAGMOGRAPHY FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of electronystagmography or videonystagmography in the evaluation of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Electronystagmography (ENG) or videonystagmography (VNG) have been used for the diagnosis of traumatic brain injury (De Clercq et al., 2017). There are no quality studies assessing electronystagmography or videonystagmography for the evaluation of patients with TBI. Studies are mostly small and have many methodological weaknesses (De Clercq et al., 2017), although positive findings have been identified (De Clercq et al., 2017, Skóra et al., 2018). Electronystagmography and videonystagmography are not invasive, have no adverse effects, are low cost, but have no quality evidence of efficacy showing meaningful impacts on evaluation and rehabilitation. Therefore, there is no recommendation for evaluation of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Electronystagmography OR ENG OR VideoNystagmoGraphy OR VNG; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 237 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 237 articles, 18 in CINAHL, 2 in Cochrane Library, 17,500 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and from other sources. Of the 2 articles considered for inclusion, 1 diagnostic study and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles,

we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ROTARY CHAIR TESTING FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against rotary chair testing for the evaluation of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients with TBI and vestibular problems that need further diagnostic evaluation

Harms

Negligible in the long term. Short-term intolerance of the testing procedures is common (Christy et al., 2019).

Frequency/Dose/Duration

Generally only assessed once. May be reasonable to do a subsequent evaluation to assess progress.

Rationale

There are few quality studies assessing rotary chair testing for the evaluation of the vestibular impacts of TBI. Available studies suggest meaningful differences when comparing concussed with non-concussed patients (Calzolari et al., 2021, Cochrane et al., 2019), while another study found no significant differences in some measures between athletes with and without concussion (Christy et al., 2019). Vestibular dysfunction is problematic and common among patients with TBI (Guise, 2010). Rotary chair testing is not invasive, has no adverse effects, is low cost, has limited evidence of diagnostic efficacy, and thus there is no recommendation for diagnosis of vestibular impacts of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Rotary chair testing; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and

reviewed 7 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 7 articles, 1 in CINAHL, 1 in Cochrane Library, 11,400 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 3 diagnostic studies and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VISION AND EYE TESTS

Visual acuity testing is the primary test used to evaluate visual function. Visual acuity testing is typically used to assess and screen the vision system for its most basic function. Visual evoked potentials (VEPs) have been used to attempt to predict outcome after brain injury [(383)]. Visual field testing is commonly used to evaluate impairments of the vision system, particularly patchy, quadrant, or hemianopsias of the visual fields. Visual field testing is not typically used as a standalone diagnostic tool for Traumatic Brain Injury. It has been used to assess the visual field defects in individuals with strokes, as well as some TBIs [(517)]. Visual perception testing involves assessing the meaning of what is seen. This contrasts with visual acuity testing, which is merely an assessment that something is seen. See the ACOEM Eye Disorders Guideline for more information.

Electroretinogram (ERG) is typically not used as a reliable diagnostic tool for TBI. Fluorescein angiography is a procedure in which a dye is injected into the bloodstream in order to highlight vessels to be photographed. This is typically used for evaluation of visual impairments. Optical coherence tomography is a technology that creates cross-sectional imaging of microstructures in the human body. Optical coherence tomography may be used as a diagnostic test to diagnose traumatic brain injuries [(518)].

VISUAL ACUITY TESTING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Visual acuity testing is recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence High

Indications

Generally only an issue with severe TBI. Significant impacts on the vision system would be additional indications.

Benefits

Identification of deficits in visual acuity.

Frequency/Dose/Duration

Generally one assessment. May be used a second time to detect improvement or resolution.

Rationale

Visual acuity testing has been used for the diagnosis of traumatic brain injury (Harris et al., 2022, Daly et al., 2022). There no quality studies assessing visual acuity testing for evaluation of TBI impairments. There are attempts to use vestibulo-ocular reflex evaluation in acute concussion settings (Marinides et al., 2015, Schneider et al., 2018, Galetta et al., 2015, Jasinovic et al., 2021). The Mobile Universal Lexicon Evaluation System (MULES) test has also been devised although there are no quality studies (Dahan et al., 2020, Cobbs et al., 2017, Fallon et al., 2019). See also the ACOEM Eye Disorders Guideline. Visual acuity testing is not invasive, has no adverse effects, is low cost, but is the primary means to evaluate impairments in visual acuity, and thus is recommended for the evaluation of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: visual acuity test; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 45 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 45 articles, 1 in CINAHL, 902 in Cochrane Library, 18,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 19 from PubMed, 0 from CINAHL, 1 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 23 articles considered for inclusion, 18 diagnostic studies and 5 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VISUAL EVOKED POTENTIALS (VEP) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Visual evoked potentials are recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Severe TBI with inability to test visual system with more common methods, such as bedside testing, or Snellen testing.

Benefits

Ability to assess the visual system

Harms

Negligible

Frequency/Dose/Duration

May be used at baseline. If there are abnormalities and the injury continues to preclude other testing, then follow-up testing with visual evoked potentials is reasonable.

Indications for discontinuation

Resolution of TBI, improvement sufficient to undergo standard vision testing.

Rationale

There are few quality studies assessing visual evoked response for diagnosis or evaluation of patients with TBI (Capó-Aponte et al., 2018, Fong et al., 2021). One moderate-quality study found multiple VEP measures correlated with acute, mild TBI (Capó-Aponte et al., 2018), while another study found a portable VEP system effective for evaluating athletes with potential acute mild TBI (Fong et al., 2021). Low-quality studies also suggest utility in the evaluation of patients with TBI (Azadi et al., 2021, Fong et al., 2020, Harris et al., 2023). VEPs are not invasive have no adverse effects, are low cost, but appear to have utility to assess the visual system when other testing is not possible, and thus have limited evidence of diagnostic efficacy, and are selectively recommended to assess the visual system when other more common testing is not possible.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: visual evoked potential test, VEP; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 16 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 16 articles, 2 in

CINAHL, 2 in Cochrane Library, 19,000 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 15 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 9 diagnostic studies and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VISUAL FIELD TESTING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Visual field testing is recommended for use in the evaluation of patients with TBI. (See the ACOEM Eye Disorders guideline for more information.)

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence High

Indications

Generally only a significant issue with severe TBI, although more subtle impairments may occur with less severe TBI cases. Significant impacts on the vision system would be additional indications.

Benefits

Identification of deficits in fields.

Frequency/Dose/Duration

Generally one assessment. May be used a second time to detect improvement or resolution.

Rationale

There are few quality studies assessing visual field testing for evaluation of TBI impairments (Das et al., 2022). See also the ACOEM Eye Disorders Guideline. Visual field testing is not invasive, has no adverse effects, is low cost, but is the primary means to evaluate impairments in visual fields and thus is selectively used for the evaluation of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Visual perception testing; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 9 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review98 articles, 1 in CINAHL, 0 in Cochrane Library, 18,300 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 1 diagnostic study and 5 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VISUAL PERCEPTUAL TESTING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Visual perceptual testing is selectively recommended for severe TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Generally only a significant issue with severe TBI, although there are reports of subtle findings among those with mild TBI (Alnawmasi et al., 2019, Benassi et al., 2021). Significant impacts on the vision system would be additional indications.

Benefits

Identification of deficits in the interpretation of visual inputs.

Frequency/Dose/Duration

Generally one assessment. May be used a second time to detect improvement or resolution.

Rationale

There are no quality studies assessing visual perceptual testing for evaluation of TBI impairments (Alnawmasi et al., 2019, Benassi et al., 2021). Visual perceptual testing is not invasive, has no adverse effects, is low cost, but is the primary means to evaluate

impairments in visual perception, and thus is selectively used for the evaluation of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: visual perceptual testing; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 88 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 88 articles, 11 in CINAHL, 30 in Cochrane Library, 18,800 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 2 diagnostic studies and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ELECTRORETINOGRAM (ERG) FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of ERG in the evaluation of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies assessing electroretinogram for diagnosis of TBI. Electroretinogram is minimally invasive, has minimal adverse effects, is moderate cost, but has no quality evidence of diagnostic efficacy in patients with TBI, and thus there is no recommendation for evaluation of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Electroretinography, ERG; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive

predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 17 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 17 articles, 0 in CINAHL, 0 in Cochrane Library, 2200 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

FLUORESCEIN ANGIOGRAPHY FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Fluorescein angiography is recommended for use in the evaluation of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Impaired visual system function where visualization of the retinal blood vessels is important.

Benefits

Assists in diagnosing select visual impairments associated with TBI.

Harms

Negligible

Frequency/Dose/Duration

Generally a one-time assessment.

Rationale

There are quality studies assessing fluorescein angiography for evaluation of patients with TBI. Fluorescein angiography is minimally invasive, has no adverse effects, and is moderate cost. Although there is not quality evidence of diagnostic efficacy in patients with TBI, it is the gold standard for evaluation of the retinal blood supply and thus is recommended for select evaluation of visual impairments associated with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Fluorescein; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and efficiency. We found and reviewed 0 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 0 articles, 0 in CINAHL, 0 in Cochrane Library, 17,500 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

OPTICAL COHERENCE TOMOGRAPHY FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of optical coherence tomography in the evaluation of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Optical coherence tomography has been used for the diagnosis of traumatic brain injury (Lyons et al., 2024). There is one quality study that showed an association between a more severe mild TBI and faster reduction in the retinal nerve fiber layer (Gilmore et al., 2020); thus, this test shows promise as a potential biomarker. A systematic review also noted few studies and found there was evidence of thinning of the retinal nerve fiber layer that might be a biomarker (Lyons et al., 2024). Optical coherence tomography is not invasive, has no adverse effects, is low cost, but in the absence of clear diagnostic utility, there is no recommendation for diagnostic evaluation of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, CINAHL, Cochrane Library, and Google Scholar with date limits of 2015 to the present using the following terms: Optical coherence tomography, OCT; traumatic brain injury, intracranial injury, closed head injury, concussion, craniocerebral injury; diagnosis, diagnostic, sensitivity, specificity, positive predictive value, negative predictive value, predictive value of tests, efficacy, and

efficiency. We found and reviewed 52 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 52 articles, 2 in CINAHL, 190 in Cochrane Library, 12,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 5 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 5 diagnostic studies and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

TREATMENT RECOMMENDATIONS

OVERVIEW

This ACOEM TBI guideline includes detailed guidance on mild, moderate, and severe TBI In the acute, subacute, and chronic phases. However, acute, severe TBI is out of scope for this guideline, due to the unique needs of this population and the use of highly heterogeneous medical and surgical interventions. This guideline does address TBI of all severities for patients who do not attain return-to-work/return-to-function status after treatment in tertiary facilities (i.e., quaternary care) to assist these patients in rehabilitation, regaining function, and achieving return-to-work status.

Regarding concussion, while most patients recover uneventfully, there also is an issue of a fine line between providing help versus promoting iatrogenesis (i.e., healthcare provider caused worsening/maintenance of symptoms due to focusing on the symptoms). Iatrogenesis is a risk especially among those with concussion and that the evaluating/treating provider should carefully consider education and intervention to promote recovery rather than unintentionally causing harm. Consideration of pre-injury factors is also all the more important in evaluation of concussion [519-522]. Among those with persistent symptoms of concussion and/or an atypical course, there should be consideration of somatic symptom disorder [523-525]. Among those with persistent concussive symptoms and/or worsening symptoms over time, there should be consideration of alternative diagnoses (e. g. metabolic causes, sleep disorders, headache syndrome, somatic symptom disorder, or secondary gain).

Most major interventions for acute, severe TBI have little to no quality evidence of efficacy, especially intra-ICU and surgical interventions; this is also particularly true where numerous combinations of treatments are typically required [526]. Treatment is necessarily complex and focused on the specific insults, deficit(s), and complications that were incurred in the event causing the TBI or ensued therefrom and require consideration of locally available resources. There are copious complex decision-making processes that must go into the decisions for immediate stabilization, treatment(s) selection and implementation for these patients (e.g., surgeries and interventional procedures including craniotomy, decompressive craniectomy, neurointerventional, tracheostomy), intracranial pressure monitoring, ventilator, sedation, feeding tube, prophylactic/primary anti-epileptic treatment [527], brain

oxygen monitoring), and multi-trauma injuries (e.g., orthopedic, chest, spinal cord, cervical spine, abdominal). Many of these decisions must be made with very little time and with an emergency/critical care response type of situation, whether in the prehospital setting, emergency department or intensive care unit.

While the ACOEM guidelines do not detail specific recommendations for interventions for these patients, there are other guidelines which may be of assistance for these acute and severe patients. These include a joint guideline published by the Congress of Neurological Surgeons and American Association of Neurological Surgeons [527-534].

The earliest phases of treatment for acute, severe brain injury are optimization of cerebral perfusion and protection against secondary injury. Thus, instead of detailed guidance, this text includes the following narrative to highlight issues of potential interest in achieving these goals, which often include the following:

1. Provide basic life support and oxygen by nasal cannula or face mask [526]
2. Manage airway, provide mechanical ventilatory support, maintain oxygen saturation at least 94%, maintain mildly low end-of-normal $PaCO_2$, provide head-of-bed elevation, place arterial and central lines, treat fever [526, 535, 536]
3. Identify extent of bodily injuries and perform diagnostic testing
4. Provide surgical interventions to address high, short-term risks (e.g., intracranial pressure)
5. Monitor and institute methods to reduce intracranial pressure, such as mannitol and hypertonic saline boluses [535, 537]
6. Sedate to address agitation or neuromuscular paralysis
7. Consider EEG monitoring

The following treatments that are frequently used to treat patients with acute, severe TBI have at least some evidence of potential efficacy:*

1. Tranexamic acid for early prevention of additional bleeding
2. Monoclonal antibodies, gepants, ergotamine, dihydroergotamine for posttraumatic headache
3. Seizure prophylaxis up to 1 week [535, 538]; consider continuous EEG monitoring in ICU
4. Seizure treatment (if ongoing seizures) beyond 1 week [535, 538]
5. Benzodiazepines for substance(s) withdrawal
6. Beta-blockers to reduce mortality
7. Glucocorticosteroids (selective use only)
8. Proton pump inhibitors, sucralfate H2 blockers for gastric protection
9. Deamino arginine vasopressin (DDAVP) for diabetes insipidus
10. Nutritional support (e.g., gastric feeding tube)
11. Surgical interventions to address high risks: decompressive craniectomy, burr holes [539, 540]
12. Methods to reduce intracranial pressure and/or preserve brain tissue/function: hyperbaric oxygen (severe only)
13. Auditory and sensory stimulation to improve cognitive function [541-547]

After medical stability is achieved, time is required for healing. Afterwards, rehabilitation is typically the primary concern. Depending on the speed of recovery, there also may be need of instituting rehabilitative evidence-based rehabilitative and treatment interventions from the subacute timeframe in the late acute phase (i.e., under 1 month after TBI).

*Some of these treatments may also be indicated for treatment of patients with TBI who are not in the acute, severe category.

ACTIVITY MODIFICATION AND EXERCISE

AQUATIC THERAPY

Aquatic therapy involves the performance of aerobic, stretching, and/or strengthening exercises in a pool. It is particularly used to minimize the effects of gravity, especially where reduced weight-bearing status is desirable.

AQUATIC THERAPY FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

A trial of aquatic therapy is selectively recommended for the treatment of subacute or chronic TBI in select patients.

Strength of evidence Recommended, Evidence (C)
Level of confidence Moderate

Indications

Patients with subacute or chronic TBI who meet criteria for referral for supervised exercise therapy and has co-morbidities (e.g., extreme obesity, significant degenerative joint disease, etc.) that preclude effective participation in weight-bearing physical activity. May also be considered when TBI impairments are sufficiently severe that removing effects of gravity improves, e.g., range of motion. Land-based exercise is generally preferable for mild TBI or for patients largely recovered, as they tend to be sustainable for most patients.

Benefits

Ability to engage in exercise and rehabilitation when unable to sufficiently tolerate weight-bearing exercises in a traditional physical or occupational therapy program. More rapid improvements in range of motion in patients with severe TBI.

Harms

May aggravate pain in a minority.

Frequency/Dose/Duration

Program should generally begin with 3 to 4 visits per week. Patient should have demonstrated evidence of functional improvement within the first 2 weeks to justify additional visits. Program should include up to 4 weeks of aquatic therapy with progression

towards a land-based, self-directed physical activity or self-directed aquatic therapy program by 6 weeks. Durations beyond 6 weeks should be limited to severe TBI patient injuries who are still demonstrating objective improvements at 6 weeks that cannot be achieved with land-based activities.

Indications for discontinuation

Non-tolerance, failure to progress or aggravation of pain or desired clinical outcome.

Rationale

Aquatic therapy has been studied for the treatment of traumatic brain injury (Xu et al., 2017). There are two moderate quality, small-sized studies involving aquatic aerobic exercise, one of severe TBI patients and the other of patients who incurred an event at last one year earlier with unclear severity (Driver et al., 2004, Curcio et al., 2020) that both suggest improved physical fitness. Aquatic therapy is not invasive, has low adverse effects, is moderate to high in cost (depending upon numbers of visits), but is likely effective. Thus, aquatic therapy is recommended for select patients.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Aquatic Therapy, Hydrotherapy, Aquatic Exercise, Water Exercise, Non-Swimming Aquatic Therapy; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 17,416 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 17,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 1 randomized trials and 1systematic reviews met the inclusion criteria. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

REST

Rest had been previously recommended because of a concern for reinjury during recovery from concussion; however, current knowledge does not indicate that rest is beneficial [548, 549, 550].

REST FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Rest is not recommended for use in the treatment of patients with TBI.

Strength of evidence Not Recommended, Evidence (C)
Level of confidence High

Rationale

There are few quality studies assessing Rest for treatment of TBI. One moderate-quality trial suggests lack of efficacy compared with usual care (Thomas DG, 2015). Rest is not invasive, has adverse effects, is low cost, has evidence of lack of efficacy, and is not recommended for treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: rest; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 17414 articles in PubMed, 0 in CINAHL, 9 in Cochrane Library, 18100 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 randomized trial and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

EXERCISE

Strengthening exercises are geared to produce improvements in maximum voluntary contraction. This improves ability to perform vocational and activities of daily living. Stretching and flexibility exercises improve range of motion. When there is a poor range of motion, function can be significantly, adversely affected. Relaxation exercises are activities that may help reduce anxiety, stress, anger, and pain [152, 551]. Relaxation is a broad topic that has many different types including physical, mental, and emotional techniques.

Aerobic exercises include brisk walking, running, swimming, and hiking. Physical activity has been suggested to “improve the learning capacity associated with long-term memory within

the brain" [552]. Exercising after injuries purportedly "stimulates repair mechanisms and enhance the functional recovery after suffering a traumatic brain injury" [552]. Aerobic exercise is believed to "improve the cognitive capacity and facilitate improved physical actions and range of motion within those who suffer from cognitive impairment" [553].

AEROBIC EXERCISE FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Aerobic exercise is recommended for use in the treatment of patients with moderate/severe subacute, chronic, or postoperative TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

For patients with subacute, chronic, postoperative, moderate, and severe TBI.

Benefits

Improved physical fitness, mood, self-esteem, and motor performance.

Harms

Negligible.

Frequency/Dose/Duration

Generally, a home exercise aerobic exercise program is prescribed on at least a daily basis, and the highest quality study targeted a sub-symptom-threshold for post concussive symptoms (Mercier et al., 2024). May require daily supervised treatment among more severely affected patients that transitions to home-based exercise program. Duration of supervised exercise is dependent on the severity of the deficits. Further durations should be based on ongoing improvements in function, particularly those that are not able to be sustained by a home-based program.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

Aerobic exercises have been studied for the treatment of traumatic brain injury, including studies of mild TBI/concussion, severe TBI and sub/acute to chronic phases (Lal et al., 2018, O'Carroll et al., 2020, Vuu et al., 2022, Leddy et al., 2023, Ivanic et al., 2024). There are multiple moderate-quality studies involving aerobic exercise which suggested efficacy of aerobic exercises (Blake et al., 2009, Bateman et al., 2001, Canning et al., 2003, Driver et al.,

2004, Mercier et al., 2024, Hassett et al., 2012, Snyder et al., 2021, Varner et al., 2021, Hutchison et al., 2022, Hoffman JM, 2010, Kolakowsky-Hayner et al., 2017). The highest-quality trial found an aerobic exercise program to be superior to a stretching program (Mercier et al., 2024). One trial found improvements in cardiovascular fitness, but no psychological or functional change (Bateman et al., 2001). One trial found benefits from aquatic treatment (Driver et al., 2004). A low-quality study found earlier exercise among collegiate athletes was associated with faster recovery (Lempke et al., 2023). Aerobic exercises are not invasive, have low adverse effects, are low to high cost (depending on supervision requirements and duration), and are recommended. They generally are to be instituted on a gradual basis using a sub-symptom threshold (Mercier et al., 2024).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Aerobic Exercise, Aerobic Exercising, Aerobic Physical Activity; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 612 articles in PubMed, 43 in CINAHL, 89 in Cochrane Library, 8050 in Google Scholar, and 0 from other sources†. We considered for inclusion 7 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 11 article considered for inclusion, 6 randomized trials and 5 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

STRENGTHENING EXERCISES FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Strengthening exercises are recommended for use in the treatment of patients with moderate/severe subacute, chronic, or postoperative TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

For patients with moderate/severe subacute, chronic, or postoperative TBI.

Benefits

Improved physical fitness, mood, self esteem and motor performance.

Harms

Negligible

Frequency/Dose/Duration

Generally prescribed on at least a daily basis. May require daily supervised treatment that transitions to home-based exercise program. Duration of supervised exercise is dependent on the severity of the deficits. Further durations should be based on ongoing improvements in function, particularly those that are not able to be sustained by a home-based program.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

Multiple moderate-quality RCTs have been reported, most of which were among patients with severe TBI. One moderate-quality trial assessed ballistic resistance training and found it superior for improving mobility that endured to a 6-month follow-up (Williams et al., 2022). One moderate-quality study found comparable efficacy between supervised and unsupervised fitness exercises (Hassett et al., 2009). Another found comparable efficacy between fitness programs that did and did not include heart rate feedback and likely primarily consisted of aerobic exercises (Hassett et al., 2012). Low-quality studies suggest potential efficacy (Plawecki et al., 2024). Strengthening exercises are not invasive, have low adverse effects, are relatively low cost (depending on supervision requirements and duration), and are recommended for TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Strengthening Exercise, Resistance Training; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 11 article in PubMed, 5 in CINAHL, 1 in Cochrane Library, 18,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 randomized trial and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

STRETCHING AND FLEXIBILITY EXERCISES FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Stretching and flexibility exercises are selectively recommended for use in the treatment of patients with moderate/severe subacute, chronic, or postoperative TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

For patients with moderate/severe subacute, chronic, or postoperative TBI.

Benefits

Improved physical fitness, mood, self esteem and motor performance.

Harms

Negligible

Frequency/Dose/Duration

Generally prescribed on at least a daily basis. May require daily supervised treatment that transitions to home-based exercise program. Duration of supervised exercise is dependent on the severity of the deficits. Further durations should be based on ongoing improvements in function, particularly those that are not able to be sustained by a home-based program.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

There are few studies involving primarily stretching and flexibility. One comparative trial found superiority of an aerobic exercise program to a stretching program (Mercier et al., 2024). One moderate-quality pilot trial suggested aerobic exercises were comparable to stretching exercises (Snyder et al., 2021). However, for nearly all disorders in the ACOEM Guidelines, stretching exercises have not been shown to be effective other than for narrow

indications where there are reductions in normal range of motion (e.g., directional stretching for low back pain). Stretching exercises are not invasive, have low adverse effects, are low to moderate cost (depending on supervision requirements and duration), and are selectively recommended for those with impaired range of motion.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Muscle Stretching Exercises, Stretching, Stretching Exercise, Flexibility Exercise; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 45 articles in PubMed, 16 in CINAHL, 78 in Cochrane Library, 17400 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

RELAXATION EXERCISES AND GROUP DISCUSSIONS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against relaxation exercises and group discussion for the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are two moderate-quality studies involving relaxation. In one study (Blake et al., 2009), Qigong somewhat improved mood and self esteem. In the other study (De Luca et al., 2014), there was improved cardiovascular function which did not translate into improved psychological function or functional independence or mobility. Thus, there are no quality studies addressing relaxation exercises. Relaxation exercises are not invasive, have low adverse effects, and are low cost. However, in the absence of quality evidence, there is no recommendation for or against relaxation exercises.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Focus Groups, Muscle Relaxation, Relaxation Exercises, Group Discussion; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 20 articles in PubMed, 3 in CINAHL, 7 in Cochrane Library, 17100 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MEDICATIONS

AMANTADINE

Amantadine is a dopamine agonist and an N-methyl-D-aspartate (NMDA) glutamate receptor antagonist [554, 555]. Amantadine has been used for treatment of patients with TBI [555-566].

AMANTADINE FOR MILD TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against amantadine for patients with mild and pre/peri/post-operative TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Moderate

Rationale

There are no quality data suggesting amantadine improves the outcomes among those with mild TBI. Thus, there is no recommendation for treatment of patients with mild, pre/peri/postoperative TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: amantadine OR

amantadin OR amantadines; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 45 articles in PubMed, 5 in CINAHL, 0 in Cochrane Library, 2930 in Google Scholar, and 0 from other sources†. We considered for inclusion 8 from PubMed, 2 from CINAHL, 0 from Cochrane Library, 7 from Google Scholar, and 0 from other sources. Of the 17 articles considered for inclusion, 8 randomized trials and 7 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

AMANTADINE FOR MODERATE OR SEVERE TRAUMATIC BRAIN INJURY (TBI)

Recommended

Amantadine is moderately recommended for patients with moderate or severe TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

Moderate-severe TBI, including penetrating injuries. Treatment in the highest quality trial was initiated from 4 to 16 weeks post TBI for treatment of functional deficits (Hammond et al., 2014)., although other successful trials enrolled patients in the acute phase. Another trial enrolled patients with irritability at 6 months after TBI and found efficacy for irritability (Hammond et al., 2014) and another trial found efficacy for aggression (Hammond et al., 2017, Hammond et al., 2024).

Benefits

Earlier resolution of disabilities

Harms

Vomiting, agitation, hypertonia, spasticity, insomnia, psychosis, hyperactivity, disorganization, vivid dreams, anorexia, aggression, delirium, and depression (Giacino et al., 2012, Gualtieri et al., 1989, Kraus et al., 1997).

Frequency/Dose/Duration

Amantadine 100 mg 2x/day, then 150 mg 2x/day at 14 days, and 200 mg 2x/day at week 4 (Giacino et al., 2012). Another quality trial used 100mg QAM and at noon (BID) for 28 days (Hammond et al., 2014).

Indications for discontinuation

Intolerance, adverse effects (see Harms)

Rationale

Amantadine has been studied for the treatment of severe traumatic brain injury patients (Mohamed et al., 2022). A high-quality RCT suggested amantadine is successful for treating functional deficits among patients with subacute to chronic severe TBI (Giacino et al., 2012). Two high-quality trials suggested accelerated functional ability benefits among those with acute severe TBI (Shimia et al., 2021) and a second trial showing improved recovery when treating in the subacute phase (Giacino et al., 2012, Whyte J, 2013). Another high-quality trial failed to find superiority for cognition, although trends towards efficacy appeared to be present at day 60 (Hammond, 2015), while a post-hoc analyses of the same study found reduced aggression (Hammond et al., 2017, Hammond et al., 2024). Moderate-quality studies report mostly similar results. Most systematic reviews have also concluded that there appears to be some efficacy of amantadine for moderate to severe TBI, including functional recovery and reduced irritability (Seifi et al., 2023, Loggini et al., 2020, Mohamed et al., 2022, Siy et al., 2024, Ter Mors et al., 2019).

Amantadine is not invasive or minimally invasive, has low adverse effects is low to moderate cost depending on route of administration, has evidence of efficacy, and is thus selectively recommended for treatment of subacute or chronic moderate to severe TBI with functional deficits, aggression, and/or irritability.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: amantadine OR amantadin OR amantadines; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 45 articles in PubMed, 5 in CINAHL, 0 in Cochrane Library, 2930 in Google Scholar, and 0 from other sources†. We considered for inclusion 8 from PubMed, 2 from CINAHL, 0 from Cochrane Library, 7 from Google Scholar, and 0 from other sources. Of the 17 articles considered for inclusion, 8 randomized trials and 7 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are

reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

AMINOSTEROIDS

Aminosteroids have been shown to inhibit lipid peroxidation in animals. Randomized controlled trials have attempted to evaluate the effectiveness of tirilazad, an aminosteroid, in humans with head injuries [567].

AMINOSTEROIDS FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Aminosteroids are not recommended for patients with TBI.

Strength of evidence Not Recommended, Insufficient Evidence (I)
Level of confidence Low

Rationale

Few studies have been performed evaluating efficacy of aminosteroids. Of these, there is one showing that the mortality rate is almost identical in both the placebo and study group. A Cochrane review represented a RCT purportedly with 1,156 subjects was to be imminently published, but extensive literature searching has failed to reveal such a study (Roberts, 2000). In another study (Marshall et al., 1998), results could not be accurately interpreted because of a potential randomization failure due to baseline "dissimilarity of prognostic variables." Thus, in the absence of quality evidence, along with strong reason to believe a negative study went unpublished, aminosteroids are not recommended for use in treating patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Aminosteroids OR pancuronium OR vecuronium, rocuronium OR rapacuronium OR dacuronium OR malouetine OR dipyrandium OR pipecuronium OR chandonium OR stercuronium; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 24 articles in PubMed, 7 in CINAHL, 11 in Cochrane Library, 4,440 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are

reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ANTIDEPRESSANTS

Antidepressants treat depressive disorders and conditions by inhibiting the uptake of certain molecules in the brain. Many studies have shown an association between this kind of head injury and depression [568-575]. Antidepressants include SSRIs, MAOIs, SNRIs, rMAO-A-inhibitors, TeCAs, NaSSAs and TCAs. When addressing TBI and depression, certain drugs, such as sertraline, have shown benefit in addressing neurobehavioral and emotional problems, but had little effect on behavioral and cognitive issues [568]. Another study addressing depression after TBI with sertraline found improved recent verbal memory, visual memory, psychomotor speed, and general cognitive efficiency [573]. Evidence remains conflicted for recommendation as other investigators have found sertraline not as effective as methylphenidate for improving cognitive function [572]. Another study aimed to reduce the incidence of depression within the first year of traumatic brain injury showed no beneficial results when sertraline was discontinued [570]. Although there is insufficient evidence for treatment of depression related to TBI, the reader is referred to the ACOEM Depressive Disorders Guideline for detailed guidance.

ANTIDEPRESSANTS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is insufficient evidence for treatment of depression related to TBI. The reader is referred to the ACOEM Depressive Disorders Guideline for detailed guidance.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Antidepressants have been studied for the treatment of traumatic brain injury (Salter et al., 2016, Paraschakis et al., 2017, Gao et al., 2019, Liu et al., 2019, Reyes et al., 2019, Cheng et al., 2021, Narapareddy et al., 2020, Peppel et al., 2020). However, there is insufficient evidence for treatment of depression related to TBI. The reader is referred to the ACOEM Depressive Disorders Guideline for detailed guidance.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Antidepressive Agents OR Antidepressants OR ssri OR selective serotonin reuptake inhibitors; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random

allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 87 articles in PubMed, 5 in CINAHL, 12 in Cochrane Library, 19,400 in Google Scholar, and 0 from other sources†. We considered for inclusion 17 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 19 articles considered for inclusion, 7 randomized trials and 8 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ANTISEIZURE PROPHYLAXIS (ANTICONVULSANTS)

Posttraumatic seizures are a frequent complication accompanying traumatic brain injuries [461, 576, 577]. Antiseizure prophylactic medications have been administered following TBI to both prevent development of seizures, as well as to reduce risk of second seizures after an initial seizure occurs after TBI [461, 576, 577].

ANTISEIZURE PROPHYLAXIS (ANTICONVULSANTS) FOR MILD TO MODERATE TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Antiseizure prophylaxis is not recommended for routine use in patients with mild or moderate TBI.

Strength of evidence Not Recommended, Insufficient Evidence (I)
Level of confidence Low

Frequency/Dose/Duration

One trial used 48 hours of phenytoin to successfully suppress seizures in the first 2 days after mild TBI (Oyemolde, 2023).

Rationale

Antiseizure prophylaxis has been studied for the treatment of mild and moderate traumatic brain injury (Chaari et al., 2017, Bakr et al., 2018, Wilson et al., 2018, Wat et al., 2019, Fang et al., 2022, Wang et al., 2022, Coelho et al., 2023, Angriman et al., 2024, Frontera et al., 2024, Karamian et al., 2024, Pease et al., 2024). One moderate-quality trial found 48 hours of phenytoin after TBI reduced seizures by 90.1% in a 1-week follow-up, however, nearly all of the seizures occurred among the minority of patients with moderate to severe TBI (Oyemolde, 2023). Another trial found no clear need of anti-epileptics for mild TBI (Manaka, 1992). One systematic review with meta-analysis relying almost entirely on retrospective studies included moderate TBI cases in the methods and concluded that the "small absolute

risk reduction and low prevalence of early seizures should be weighed against potential acute risks of antiseizure medications as well as the risk of inappropriate continuation beyond 7 days (Pease et al., 2024). Seizure prophylaxis is not invasive, has minimal short-term adverse effects but significant management issues over intermediate to long term, and thus it is generally not recommended for patients with mild to moderate TBI; however, a short course (e.g., 48 hours) of an antiepileptic may be reasonable in select cases.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: antiseizure prophylaxis OR anticonvulsant drugs or anti seizures medications or anti epileptic **;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 224 articles in PubMed, 2077 in CINAHL, 2189 in Cochrane Library, 8500 in Google Scholar, and 0 from other sources†. We considered for inclusion 37 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 22 from Google Scholar, and 0 from other sources. Of the 59 articles considered for inclusion, 7 randomized trials and 20 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ANTISEIZURE PROPHYLAXIS (ANTICONVULSANTS) FOR SEVERE TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against antiseizure prophylaxis for severe or postoperative traumatic brain injury. If the benefits are determined to outweigh the risks, then the use of antiseizure prophylaxis is not recommended to exceed 1 week.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Antiseizure prophylaxis has been studied for the treatment of severe traumatic brain injury (Yang et al., 2016, Chaari et al., 2017, Bakr et al., 2018, Zhao et al., 2018, McGinn et al.,

2022, Wang et al., 2023, Karamian et al., 2024). Placebo-controlled trials found phenytoin prevented early seizures (Temkin et al., 1990, Haltiner AM, 1999) and another trial found 48 hours of phenytoin reduced seizures risk 90.1% over the first week (Oyemolde, 2023). One trial without placebo reported a trend towards more mortality in the valproate arm (13.4% vs. 7.2%, p=0.07) (Hanks et al., 1999). Comparative trials found equivalency between phenytoin and levetiracetam (Inaba et al., 2013), equivalency between phenytoin and valproate (Temkin et al., 1999, Dikmen et al., 2000), superiority of levetiracetam to phenytoin (Younus et al., 2018), superiority of IV preparations of levetiracetam for disability but not seizure prevention (Szaflarski et al., 2010), equivalency of IV penytoin to levetiracetam (Inaba et al., 2013), and superiority of levetiracetam to valproate (Wang et al., 2023). A comparative trial of 7 vs 21 days of phenytoin found no benefit for the longer treatment duration (Kumar et al., 2022). Levetiracetam was associated with fewer late seizures compared with valproate in one trial (Wang et al., 2023). Lack of efficacy of phenobarbital has also been reported (Manaka, 1992). Cessation of phenytoin was reportedly associated with improvements in cognition (Dikmen SS, 1991).

Systematic reviews and meta-analyses found modest evidence of efficacy of antiepileptics to prevent early seizures after TBI (Wat et al., 2019), and no evidence that early use is associated with higher seizure risk at 18-to-24 months (Coelho et al., 2023). Systematic reviews and meta-analyses also found no to minimal benefits regarding safety of levetiracetam compared with phenytoin (Bakr et al., 2018, Chaari et al., 2017, Karamian et al., 2024, Khan et al., 2016, McGinn et al., 2022, Meshkini et al., 2015, Wang et al., 2022, Yang et al., 2016, Wilson et al., 2018, Xu et al., 2016, Zhao et al., 2018, Angriman et al., 2024).

Seizure prophylaxis is not invasive and has minimal short-term adverse effects, but there are significant management issues as well as potential cognitive impairment issues over the intermediate to long term; thus, there is no recommendation for or against use in patients with severe or postoperative TBI. Up to a 1 week of an antiepileptic course after moderate-to-severe TBI is less controversial (Hawryluk et al., 2019, Frontera et al., 2024), and treatment with antiepileptics when a diagnosis of epilepsy is established is also routine; however, long-term use without establishing a diagnosis of epilepsy is not recommended. Selective longer-term use requires assessing risk of the development of epilepsy (e.g., seizure occurrence more than 48 hours after TBI, dural penetration, EEG abnormalities, type of surgery), while balancing multiple factors, including risks of future seizures, complications of seizures, occupational prohibitions against anti-epileptic use, and inability to demonstrate sufficient seizure-free intervals off antiepileptics to resume safety-critical work.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Anticonvulsants OR antiseizure prophylaxis; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and

reviewed 104 articles in PubMed, 8 in CINAHL, 27 in Cochrane Library, 8,130 in Google Scholar, and 0 from other sources†. We considered for inclusion 17 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 17 from Google Scholar, and 0 from other sources. Of the 34 articles considered for inclusion, 9 randomized trials and 9 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ANTISPASTICITY MEDICATIONS (NOT INCLUDING BOTOX)

Antispasticity medications are typically administered to relieve muscle pain and muscle spasms. Patients may experience post-TBI spasticity events, or side effects, that can reduced by these agents [578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588]. Certain muscle relaxants, such as suxamethonium, offer sedative and relaxing properties without increasing intracranial pressure or reducing cerebral perfusion pressure [589].

ANTISPASTICITY MEDICATIONS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Antispasticity medications are selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Muscle spasticity and dystonia associated with TBI.

Benefits

Reduce muscle spasticity.

Harms

Slowed mentation, fatigue, somnolence, dizziness, blurred vision, confusion, headache, bradycardia, hypotension, anxiety, nausea, elevated liver enzymes, constipation.

Frequency/Dose/Duration

One successful trial initiated tizanidine and gradually increased the dose to 36 mg/day.

Indications for discontinuation

Resolution, intolerance, noncompliance, adverse effects.

Rationale

Antispasticity has been mostly studied for the treatment of patients with severe TBI (Synnot et al., 2017). There is one moderate-quality RCT (Meythaler et al., 2001) comparing tizanidine to placebo, which suggested improvements in spasticity and hypertonia. There are two moderate-quality studies showing comparable efficacy. A Cochrane review concluded there were concerns about the "very low" quality of the evidence and drew "any firm conclusions" (Synnot et al., 2017). Thus, muscle relaxants are selectively recommended for treatment of spasticity and hypertonia. They have separate indications for other sequelae of accidents (e.g., see the ACOEM Cervical and Thoracic Disorders and Low Back Disorders Guidelines).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Anti-spasticity OR baclofen OR tizanidine OR dantrolene OR diazepam; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 49 articles in PubMed, 1 in CINAHL, 29 in Cochrane Library, 15,200 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trial and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ATYPICAL ANTIPSYCHOTICS

Atypical antipsychotics have been used to treat psychotic disorders [590]. These drugs are classified as atypical due to an association with lower risk of causing extrapyramidal signs and symptoms (EPS) [591, 592]. Controversy surrounds the usage of these drugs for TBI treatment [593].

ATYPICAL ANTIPSYCHOTICS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Atypical antipsychotics are selectively recommended for treatment of patients with TBI with agitation from mood disorders, typically among those with insufficient efficacy from an antidepressant.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

For the treatment of agitation in patients with mood disorders, generally when an antidepressant has proven to be insufficiently effective.

Benefits

Improvement in agitation and mood disorder symptoms in patients with TBI.

Harms

Intolerance, weight gain, fatigue, drowsiness, insomnia, dry mouth, blurred vision, drug-drug interactions. Caution is warranted in those with hypothalamic pituitary dysfunction and epilepsy.

Frequency/Dose/Duration

Per manufacturer's recommendations

Indications for discontinuation

Resolution of or significant improvement in agitation. Development of hypothalamic pituitary dysfunction.

Rationale

There are no quality studies for the use of atypical antipsychotics to treat agitation specifically in patients with TBI. Some data suggest efficacy (Lombard et al., 2005, Kim et al., 2002, Levy et al., 2005, Chew et al., 2009). Atypical antipsychotics are not invasive, have some adverse effects and are low to moderate cost, and are selectively recommended among patients for whom an antidepressant has proven insufficiently effective.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: antipsychotics, traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic

review, retrospective, and prospective studies. We found and reviewed 6 articles in PubMed, 0 in CINAHL, 1 in Cochrane Library, 7700 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BACLOFEN, INTRATHECAL (PUMP)

INTRATHECAL BACLOFEN (ITB) PUMP FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Intrathecal baclofen is recommended for highly selective use among patients with TBI having insufficiently controlled muscle spasticity and dystonia.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

For treatment of severe, chronic muscle spasticity and dystonia associated with TBI that is unable to be sufficiently controlled through non-invasive means that included other pharmaceutical, including baclofen at 80-160mg/day. Also should have considered and tried at least one of: diazepam, clonidine and/or dantrolene (Meythaler et al., 1996). Should have severe hypertonia sufficient to interfere with activities of daily living (Meythaler et al., 1996). That single quality trial required at least one year with these indications prior to inclusion in the trial, as well as Ashworth score at least 3, and average spasm score at least 2.

Benefits

Reduced muscle spasticity and ability to better accomplish normal activities.

Harms

Drowsiness, weakness, dizziness, headache, seizures, nausea, vomiting, constipation, hypotension, confusion, fatigue, respiratory depression, insomnia, increased urinary frequency, urinary retention, adverse events, infections, paralysis, and death.

Frequency/Dose/Duration

Intrathecal test dose of 50 mcg in a volume of 1 mL injected into the intrathecal space by barbotage over at least 1 minute. Generally at least two trials of saline and intrathecal dose of baclofen are used to confirm efficacy before consideration of implantation of an intrathecal pump.

Indications for discontinuation

Sufficient resolution of symptoms, often after a trial of turning the device off. Infections, complications, intolerance.

Rationale

There is one moderate-quality study (Meythaler et al., 1996) and one lower-quality study (Meythaler et al., 1999) showing some efficacy in reducing spasticity and dystonia in bilateral extremities. Both studies were compared to placebo and both had small sample sizes. Neither involved implantation of a pump system. Baclofen administered intrathecally (especially by a pump) is invasive, has considerable adverse effects, and is costly; however, the data indicate that it may be effective for a highly select patient group.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: baclofen OR intrathecal baclofen pump OR baclofen pump; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 28 articles in PubMed, 1 in CINAHL, 8 in Cochrane Library, 1,930 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BARBITURATES

Barbiturates serve as central nervous system depressants. After traumatic brain injury, certain barbiturates, such as pentobarbital, have been used to attempt to control refractory intracranial hypertension that can result from surgery or medical treatment [594-600].

BARBITURATES FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Barbiturates are not generally recommended for the treatment of TBI. There are indications for patients with acute, severe TBI.

Strength of evidence Not Recommended, Evidence (C)
Level of confidence Low

Rationale

There are two moderate-quality studies of barbiturates for treatment of severe TBI. In one study, mannitol was considerably superior to pentobarbital for reducing mortality (41% vs. 77%) (Schwartz et al., 1984). The other trial used a control arm that is no longer substantially used (Eisenberg et al., 1988). Because there is moderate quality evidence that mannitol is superior to pentobarbital, use of barbiturates is not recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: barbiturates; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 28 articles in PubMed, 15 in CINAHL, 26 in Cochrane Library, 10,600 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 0 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BENZODIAZEPINES

Benzodiazepines are typically used to treat anxiety, depression, panic attacks, nausea, seizures, vomiting and muscle spasms, but can also be used for sedation [601, 602, 603, 604]. After experiencing a traumatic brain injury, benzodiazepines have been used to provide sedation before procedures, but effectiveness over other sedative agents is purportedly unclear [601, 602, 603, 604, 605].

BENZODIAZEPINES FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Benzodiazepines are not indicated for treatment of patients with TBI. Benzodiazepines are selectively recommended for treatment of patients with discrete indications, including spasticity secondary to TBI and persistent vestibular dysfunction unresponsive to other interventions.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Not for use solely for TBI. Uses include discrete issues with alcohol withdrawal. As benzodiazepines have major adverse effects including problems with dependency, impair memory and cognitive recovery, those patients with TBI requiring a course of benzodiazepines after TBI (e.g., alcohol withdrawal) should be tapered as soon as practical. See the ACOEM Anxiety Disorders Guideline for management of anxiety and panic attacks.

Benefits

Reduced risk of seizures with alcohol withdrawal

Harms

Respiratory sedation, CNS depression, confusion, dizziness, addiction, dependency.

Frequency/Dose/Duration

As per manufacturer's recommendations

Indications for discontinuation

Sufficient resolution of the symptoms that necessitated treatment.

Rationale

There are few quality studies evaluating benzodiazepines in patients with moderate to severe TBI. There is only one moderate-quality study (Ghori et al., 2007) finding comparable efficacy between midazolam and propofol. No studies were compared to placebo. Thus, evidence specific to TBI is limited. Benzodiazepines are not invasive, have major adverse effects, and are low to moderate cost. They are not indicated for treatment of TBI and are generally not indicated for treatment of anxiety disorders (see the ACOEM Anxiety Disorders Guideline) or insomnia. However, they may have discrete, narrow indications, such as for treatment of alcohol withdrawal symptoms.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Benzodiazepines OR Xanax OR Valium OR Halcion OR Ativan OR Klonopin; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 34 articles in PubMed, 3 in CINAHL, 24 in Cochrane Library, 17,200 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BETA BLOCKERS

Beta blockers prevent the stimulation of the adrenergic receptors. After experiencing a traumatic brain injury, catecholamines form in response to excitatory neurotransmitters. This surge purportedly results in poor neurological outcomes and secondary injury [606-609]. Beta blockers are believed to assist in controlling the effects of intracranial hemorrhaging, tachycardia, hypertension and intensity of agitation [558, 606-617].

BETA-BLOCKERS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Beta-blockers are selectively recommended for treatment of hospitalized patients with severe TBI. There are other indications for these medications.

Strength of evidence Recommended, Evidence (C)
Level of confidence Moderate

Indications

Selectively recommended for treatment of acute severe hospitalized patients to reduce mortality. There are other indications for beta-blockers (e.g., tachycardia, hypertension).

Benefits

Reduced mortality. Cessation of tachycardia and/or normalization of blood pressure.

Harms

Increased ventilator days. Bradycardia, syncope, dizziness, drowsiness, fatigue, dry mouth.

Frequency/Dose/Duration

Per manufacturer's recommendations.

Indications for discontinuation

When tachycardia symptoms resolve or other adverse events.

Rationale

Beta-blockers have been studied for the treatment of mostly severe traumatic brain injury patients (Alali et al., 2017, Chen et al., 2017, Zagales et al., 2023, Ding et al., 2021, Flores-Sandoval et al., 2024, Florez-Perdomo et al., 2021). Multiple quality trials have shown a reduction of in-hospital mortality from approximately 61 to 77% among patients with severe TBI attributed to beta-blockade (Khalili et al., 2020, Schroeppel et al., 2019), which corroborate cohort study data (see below), although beta-blockers are also accompanied by longer need of ventilators, longer length of stay, and higher infection rates.

One moderate-quality RCT found no reduction in ventilator days associated with propranolol (Nordness et al., 2023). Another trial showed that atenolol reduced supraventricular tachycardia and ST-segment and T wave changes as well as appearance of less necrosis at autopsy (CRUICKSHANK et al., 1988). One trial found landiol effective for controlling tachycardia (Kawaguchi et al., 2010). A third trial addressed intubation and is thus not included here (Levitt et al., 2001). One RCT analyzed biomarkers and found reductions in biomarkers attributed to propranolol (El-Menyar et al., 2024). Systematic reviews and meta-analyses found consistent evidence of reductions in mortality; however, they also found adverse effects, such as longer need for ventilators, intensive care management, longer length of stay, and higher infection rates (Alali et al., 2017, Chen et al., 2017, Ding et al., 2021, Florez-Perdomo et al., 2021, Zagales et al., 2023),

Beta-blockers are either not invasive or minimally invasive, have modest risks, are low to moderate cost, and have evidence of efficacy for purposes of reducing mortality among patients with severe TBI. They are selectively recommended for treatment of these patients. The benefits of ongoing treatment after the acute phase have not been shown specifically for patients with TBI, but may be inferred based on treatment of either tachycardia and/or hypertension and thus are recommended by expert consensus. There are other uses of beta-blockers, especially for tachycardia and hypertension.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Beta-blocker; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled

clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 66 articles in PubMed, 4 in CINAHL, 22 in Cochrane Library, 19,200 in Google Scholar, and 0 from other sources†. We considered for inclusion 18 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 18 articles considered for inclusion, 5 randomized trials and 5 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CABERGOLINE

Cabergoline is an ergot derivative, dopamine receptor agonist, lowers prolactin levels, and has a similar use profile as bromocriptine. Deamino arginine vasopressin is used to treat diabetes insipidus, as well as hypernatremia [618, 619]. Memantine has been studied in rat models and is thought to have neuroprotective potential for patients with TBI [620, 621]. Substance P is proposed to have an important role in edema, and thus antagonists are proposed as neuroprotective [622, 623].

CABERGOLINE FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against cabergoline for patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies of cabergoline and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: cabergoline**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 888 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane

Library, 2 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 1 randomized trial and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CANNABINOIDS

Dexanabinol (HU-211) is a synthetic, nonpsychotropic cannabinoid that has been suggested as a neuroprotective drug. This drug purportedly differs from other neuroprotective drugs because it targets various pathophysiological mechanisms, which include glutamate excitotoxicity, free radical damage, and inflammatory response. Dexanabinol is suggested to be most protective against the breakdown of the blood-brain barrier, reduces edema formation, decreases the number and severity of neurological problems and has been used for treatment of patients with TBI [624, 625]. Endocannabinoids have also been used to treat patients with TBI [626].

CANNABINOIDS FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Cannabinoids are not recommended for the treatment of patients with TBI. See the ACOEM Cannabis Guideline.

Strength of evidence Not Recommended, Insufficient Evidence (I)
Level of confidence Low

Rationale

The overall breadth and depth of literature on cannabis is sparse (see the ACOEM Cannabis Guideline). A high-quality trial of dexanabinol suggested no benefits of a single early dose on 6-month outcomes (Maas et al., 2006). A moderate-quality trial suggested lower intracranial pressures and a trend but no clear evidence of better long-term survival (Knoller et al., 2002). A moderate-quality trial of a cannabinoid CB1/CB2 receptor agonist suggested potential modest short-term efficacy with lower intracranial pressures and short-term survival but no evidence of long-term benefits (Firsching et al., 2012). With a lack of clear evidence of efficacy and the highest quality study being negative, and major adverse effects, cannabis is not recommended for treatment of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: cannabinoids; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury,

concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 10 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 15,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 5 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 1 randomized trial and 7 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CEREBROLYSIN

Cerebrolysin is a neuropeptide preparation, which mimics endogenous neurotropic factor action on the brain and is thought to decrease amyloid production. It has also been used in patients with dementia and Parkinson's disease [627].

CEREBROLYSIN FOR TRAUMATIC BRAIN INJURY (TBI) (NOT CURRENTLY APPROVED FOR USE IN U. S.)

No Recommendation

There is no recommendation for or against cerebrolysin for treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Indications

Moderate to severe TBI. The highest quality study included TBI patients with a GCS of 7-12, Marshal classification of CT I to VI, pre-trauma Kamofsky Index =100. Patients were excluded who had polytrauma (AIS score in other body regions of >2), penetrating brain injury, spinal cord injury, history of intracranial interventions (including ischemic or hemorrhagic stroke), pre-existing major health conditions, use of cortisone, calcium channel blockers, antidepressants, antipsychotic drugs, nootropic molecules, other non/neurological conditions that would influence outcomes, intoxication, and signs of addiction (Muresanu et al., 2020).

Benefits

Improved Glasgow outcomes scale, processing speed index, digit symbol coding, Digit span digit forward test, Digit span digit backwards test, Stroop (VST) word/dots interference, and depression sum score.

Harms

Leukocytosis, "agitation (aggressiveness, insomnia, rarely hallucinations), confusion, tremor, allergic reactions–very rare, in our expertise (fever, skin reactions, pruritus, local vascular reactions, headache, neck pain, limb pain, lower backache, dyspnea, chills, shock–like state), vertigo, headache, hypertension or hypotension, hyperventilation, hypertonia or hypotonia, fatigue, depression, apathy, flu–like symptoms, gastro–intestinal troubles (loss of appetite, dyspepsia, diarrhea, constipation, nausea, vomiting), rapid injection may cause heat sensation, sweatiness, dizziness, rarely palpitations or cardiac arrhythmias, injection site reactions (irritation, pruritus, burning sensation)" (Onose G, 2009).

Frequency/Dose/Duration

Cerebrolysin dose was not defined in the highest quality trials, instead only volume was described as: diluted in 0.9% NS to 250mL, 50mL for days 1-10 and 10mL for days 31-40, 61-70 (Muresanu et al., 2020).

Indications for discontinuation

Intolerance, adverse effects.

Rationale

Cerebrolysin has been studied for the treatment of mostly moderate to severe traumatic brain injury (Ghaffarpasand et al., 2018, Fiani et al., 2021). Two high-quality trials by the same research group both showed evidence of efficacy compared with placebo (Muresanu et al., 2016, Poon et al., 2020). Two moderate-quality RCTs of cerebrolysin, a pilot study (Chen et al., 2013) and an exploratory RCT (Muresanu et al., 2016), on 208 patients with ischemic stroke suggested potential efficacy. A three-arm RCT compared cerebrolysin and rTMS, suggesting potential synergistic benefits with both active treatments (Verisezan Rosu et al., 2023). However, studies have not clearly defined the dose, instead only identifying volume of the drug (mL). One systematic review and meta-analysis included mostly cohort study patients (Ghaffarpasand et al., 2018). While quality data suggest efficacy, the dose must be well established to support a favorable recommendation; thus, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Cerebrolysin; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 27 articles in PubMed, 2 in CINAHL, 14 in Cochrane Library, 746 in Google Scholar, and 0 from other

sources†. We considered for inclusion 8 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 5 from Google Scholar, and 0 from other sources. Of the 13 articles considered for inclusion, 6 randomized trials and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CITICOLINE

Choline is an intermediary of acetylcholine, a neurotransmitter that helps in central and peripheral nervous system functions such as arousal, motor functioning, cognitive functioning, and memory. Cytidine 5'-diphosphocholine (CDP-choline or citicoline) is a naturally occurring source of choline supplementation that may provide neuroprotection and repair as well as improve cognitive symptoms months to years after injury. In the US, CDP-choline is considered a supplement whereas in other countries, such as Europe and Japan, it is considered a pharmaceutical drug that is prescribed [628]. In TBI, CDP-choline purportedly may be beneficial for neuroprotection during the secondary injury phase and for neurofacilitation for improving recovery throughout rehabilitation [378, 628, 629, 630, 631, 632, 633].

CITICOLINE FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Citicoline is not recommended for treatment of TBI.

Strength of evidence Not Recommended, Evidence (C)
Level of confidence Low

Rationale

Citicoline has been studied for the treatment of traumatic brain injury (Meshkini et al., 2017, Khormali et al., 2022, Secades et al., 2023). There are two moderate-quality trials involving citicoline. One very large study was terminated early for lack of utility (Zafonte et al., 2012, Puffer et al., 2019). The other study was much smaller and suggested a slight benefit (Levin, 1991). As citicoline has no evidence of efficacy in a very large placebo-controlled trial, it is not recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Citicoline; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled

clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 24 articles in PubMed, 0 in CINAHL, 8 in Cochrane Library, 986 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 5 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 4 randomized trials and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMPLEMENTARY AND ALTERNATIVE MEDICINE

Complementary and alternative medications and homeopathy have been used for treatment of patients with TBI [634, 635, 636].

BOSWELLIA SERRATA FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against *Boswellia serrata* for patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Two moderate-quality trials suggested benefits (Meshkat et al., 2022, Yousefi et al., 2022), while another moderate-quality pilot study of *Boswellia serrata* reported a nonsignificant trend (Moein et al., 2013), . *Boswellia serrata* dosing is not standardized; thus, there is no recommendation for or against *Boswellia serrata*.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Boswellia Serrata; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 1,130 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane

Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 2 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

OTHER ALTERNATIVE, COMPLEMENTARY, HOMEOPATHIC TREATMENTS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against other alternative, complementary, or homeopathic treatments for patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Homeopathic treatments were evaluated in two low-quality studies (Sun et al., 2009, Chapman et al., 1999) among patients 3 years after injury (Chapman et al., 1999). Thus, there is no quality evidence and no recommendation for or against other complementary, alternative, or homeopathic treatments for TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: alternative, complementary, homeopathic treatments **;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 137 articles in PubMed, 63 in CINAHL, 6 in Cochrane Library, 18,600 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CORTICOSTEROIDS

Corticosteroids have been used for treatment of acute TBI. The effect of corticosteroids on the risk of death has been reported in a past [637].

CORTICOSTEROIDS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Glucocorticosteroids are selectively recommended for treatment of subdural TBI, especially when surgery is felt to not be indicated, as the recurrence rate is reduced although psychiatric complications are elevated (Zhao et al., 2022).

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Chronic subdural hematoma that is felt to require treatment, but there is desire to avoid surgery or significant risks associated with surgery. There is not evidence of efficacy for treatment of acute TBI.

Benefits

Reduced risk of subdural hematoma recurrence and need of surgical evacuation.

Harms

Insomnia, diabetes, worsened glucose control, delirium, mood swings, restlessness, infection, fatigue, weakness, weight gain, edema.

Frequency/Dose/Duration

A high-quality trial used a course of dexamethasone 8 mg BID that was then tapered over 2 weeks (Hutchinson et al., 2020), while another moderate-quality trial used dexamethasone 8 mg BID tapered over 19 days (Miah et al., 2023).

Indications for discontinuation

Completion of a course, adverse effects, noncompliance.

Rationale

Corticosteroids have been studied for the treatment of traumatic brain injury (Zhao et al., 2022, Shrestha et al., 2022), with evidence of differing results for different indications.

There is one high-quality, placebo-controlled study of dexamethasone vs. placebo for chronic symptomatic subdural hematomas, and that trial found a 7% lower risk of a favorable outcome if given the steroid, while the risk of surgery for recurrence was 1.7% in the steroid group vs. 7.1% in the placebo group (Hutchinson et al., 2020). A moderate-quality study of dexamethasone vs. surgery for chronic subdural hematoma was stopped early due to adverse effects in the steroid group and found greater disability, higher need of surgery in the glucocorticosteroid group (55% vs. 6%), and higher complications (59% vs. 32%) (Miah et al., 2023). A trial of prednisone for adjunctive treatment to surgery for chronic subdural hematoma reported a radiological recurrence rate of 21.8% with prednisone vs. 35.1% with placebo (Ng et al., 2021). A systematic review with meta-analysis concluded glucocorticoid therapy reduced risk of recurrent chronic subdural hematoma by 60%, did not improve neurological outcomes while being associated with a 3.2-fold increased risk of psychiatric symptoms (Zhao et al., 2022). A network analysis of 455 studies with 103,645 cases reported that glucocorticosteroids reduced the risk of chronic subdural hematoma recurrence by 53%, but were associated with a 34% increased risk of morbidity (Henry et al., 2022).

There are multiple moderate-quality studies involving glucocorticosteroids for treatment of acute TBI and most of these report lack of efficacy to either reduce mortality or improve clinical outcomes (Roberts et al., 2004, Brackman et al., 1983, Cooper et al., 1979, Dearden et al., 1986, Saul et al., 1981).

Separately, glucocorticoids have evidence of efficacy for traumatic hyphemia (see the ACOEM Eye Guideline).

Glucocorticosteroids are either not invasive or minimally invasive depending on route of administration, have significant adverse effects, are low cost, but have some evidence for efficacy for reducing recurrence risk of subdural hematoma, while being inferior to surgery for risk of reoperation. Thus, glucocorticoids are selectively recommended for treatment of highly select cases of TBI with chronic symptomatic subdural hematomas where the balancing of risks of recurrence against adverse effects is felt to be favorable (e.g., high surgical risks). There is not evidence of efficacy for treatment of acute TBI to either reduce mortality or improve clinical outcomes.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Corticosteroids**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 164 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 18,300 in Google Scholar, and 0 from other sources†. We considered for inclusion 5 from PubMed, 0 from CINAHL, 0 from Cochrane

Library, 0 from Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 2 randomized trials and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CYTOPROTECTIVE DRUGS

There are two main reasons for using cytoprotective drugs in patients with TBI: [217] prevention of stress ulcers, and to (2) counteract NSAID-related effects on the GI tract. There are four commonly used cytoprotective classes of drugs – proton pump inhibitors (esomeprazole, lansoprazole, omeprazole, pantoprazole, rabeprazole), misoprostol, sucralfate, and histamine Type 2 receptor blockers (famotidine, ranitidine, cimetidine, etc.). There is not generally believed to be substantial differences in efficacy for prevention of gastrointestinal bleeding [638].

PROTON PUMP INHIBITORS (PPIS) FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Proton pump inhibitors are strongly recommended for use with NSAIDs for select patients with TBI, especially in the acute severe stage.

Strength of evidence Strongly Recommended, Evidence (A)
Level of confidence High

Indications

NSAID use with either risk factors for GI bleeding (e.g., elderly, diabetes mellitus, rheumatoid arthritis), or ICU stay and concerns for gastric ulcers. May be needed for others at high risk of GI bleeding in the subacute and chronic stages.

Benefits

Eliminates increased risk of GI bleeding from NSAIDs. May reduce risk of stress ulcers.

Harms

Adverse effects of the proton pump inhibitor. Concerns for higher bacterial burden in the stomach with lack of low pH and thus increased risk of bacterial pneumonia from aspiration, making suggestions sucralfate or possibly H2 blockers may be preferable for that indication (Fohl et al., 2011, Herzig et al., 2009).

Frequency/Dose/Duration

Dose and frequency for proton pump inhibitors, sucralfate, and H2 blockers are as recommended by manufacturer. Duration is the extent of the NSAID therapy; use is at times permanent for those with recurrent bleeds or other complications.

Rationale

Risks of gastrointestinal events are recommended for assessment, particularly including prior history of gastrointestinal bleeding and source, length of treatment, age, smoking, diabetes mellitus and other medical factors. Those with greater risk should be considered for treatment with acetaminophen, NSAID plus misoprostol, proton pump inhibitors (see below), or a COX-2 selective agent (see NSAIDs/acetaminophen evidence table) (Nelson et al., 2015, Echemendia et al., 2016, Townend et al., 2006, Snyder et al., 2014, Greve et al., 2006, McCusker PJ, 2003, Fenton et al., 2004, Garner et al., 2005, Berenbaum et al., 2005, Agrawal et al., 1999, Bocanegra et al., 1998, Melo Gomes et al., 1993).

Gastrointestinal adverse events are generally considered the most significant of the risks of NSAIDs. A large volume of high- and moderate-quality evidence consistently shows proton pump inhibitors are effective for prevention and or treatment of gastric and duodenal ulcers and erosions (Arbisi et al., 2011, Alkemade et al., 2015, Edmundson et al., 2016, Jones, 2016, Pape et al., 2016, Lange et al., 2015, Bolinger et al., 2013, Goodwin et al., 2013, Peck et al., 2013, Whitney, 2013, Scheiman et al., 1994, Scheiman et al., 2006, Chan et al., 2002, Regula et al., 2006, Yeomans et al., 2008, Bianchi, 1998, Bianchi, 2000, Hawkey et al., 2005, Desai et al., 2008, Bergmann et al., 1992). There is only one quality head-to-head trial, and it found no difference in efficacy between pantoprazole and omeprazole (Edmundson et al., 2016, Scheiman et al., 2006). Misoprostol has also been consistently shown to be effective compared with placebo (Coggon et al., 2013, Lezak, 2004, Wechsler, 1997, Donders et al., 2001, Donders et al., 2015, Rabin et al., 2005, Reid-Arndt et al., 2011, Miller et al., 2004, Greve et al., 2003, Greve et al., 2008) (Graham et al., 2002, Raskin et al., 1995) (Elliott et al., 1994, Chandrasekaran et al., 1991, Lanza et al., 1988, Jiranek et al., 1989, Donnelly et al., 2000, Medina Santillan et al., 1999, Koch et al., 2000). Relatively fewer studies have shown sucralfate to be effective compared with placebo (Mathias et al., 2002, Miglioli et al., 1996); H2 blockers appear more effective for treatment of duodenal than gastric mucosa (Leong et al., 2014, Walsh et al., 2016, Vernau et al., 2015, Robinson et al., 1989, Robinson et al., 1991, Ehsanullah et al., 1988). There are relatively few quality trials comparing efficacy of the different classes of agents. Pantoprazole but not lansoprazole has been found modestly superior to misoprostol (Liedes et al., 2015, Wilbur et al., 2008, Stupnicki et al., 2003, Graham et al., 2002). No difference was found between famotidine and lansoprazole (Walker et al., 2009, Miyake et al., 2005). Misoprostol has been reported superior to ranitidine (Strong et al., 2005, Curtis et al., 2009, Miglioli et al., 1996, Raskin et al., 1995), cimetidine (Langeluddecke et al., 2003, Lanza et al., 1988), and sucralfate (Rabin et al., 2005, Fisher et al., 2000, Agrawal et al., 1991, Lanza et al., 1988).

In short, while the evidence is not definitive, available quality evidence suggests proton pump inhibitors and misoprostol appear superior to H2 blockers and sucralfate. While COX-2 selective agents have generally been recommended as either third- or fourth-line medications for routine use in osteoarthrosis patients, when there is a risk of

gastrointestinal complications, they are often preferred. For patients at high risk of gastrointestinal bleeding, there is evidence that a combination of proton pump inhibitor plus COX-2 selective agent is efficacious (Ryan et al., 2005, Goldstein et al., 2006).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Proton Pump Inhibitor**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 2 in CINAHL, 1 in Cochrane Library, 8490 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SUCRALFATE FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Sucralfate is selectively recommended for treatment of patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

NSAID use with either risk factors for GI bleeding (e.g., past history of GI bleeding, elderly, diabetes mellitus, rheumatoid arthritis), or ICU stay and concerns for gastric ulcers. May be needed for others at high risk of GI bleeding in the subacute and chronic stages.

Benefits

Eliminates increased risk of GI bleeding from NSAIDs. May reduce risk of stress ulcers.

Harms

Adverse effects of the proton pump inhibitor. Concerns for higher bacterial burden in the stomach with lack of low pH and thus increased risk of bacterial pneumonia from aspiration, making suggestions sucralfate or possibly H2 blockers may be preferable for that indication (Fohl et al., 2011, Herzig et al., 2009).

Frequency/Dose/Duration

Dose and frequency for proton pump inhibitors, sucralfate, and H2 blockers are as recommended by manufacturer. Duration is the extent of the NSAID therapy; use is at times permanent for those with recurrent bleeds or other complications.

Rationale

Risks of gastrointestinal events are also recommended for assessment, particularly including prior history of gastrointestinal bleeding and source, length of treatment, age, smoking, diabetes mellitus and other medical factors. Those with greater risk should be considered for treatment with acetaminophen, NSAID plus misoprostol, proton pump inhibitors (see below), or a COX-2 selective agent (see NSAIDs/acetaminophen evidence table) (Nelson et al., 2015, Echemendia et al., 2016, Townend et al., 2006, Snyder et al., 2014, Greve et al., 2006, McCusker PJ, 2003, Fenton et al., 2004, Garner et al., 2005, Berenbaum et al., 2005, Agrawal et al., 1999, Bocanegra et al., 1998, Melo Gomes et al., 1993).

Gastrointestinal adverse events are generally considered the most significant of the risks of NSAIDs. A large volume of high- and moderate-quality evidence consistently shows proton pump inhibitors are effective for prevention and or treatment of gastric and duodenal ulcers and erosions (Arbisi et al., 2011, Alkemade et al., 2015, Edmundson et al., 2016, Jones, 2016, Pape et al., 2016, Lange et al., 2015, Bolinger et al., 2013, Goodwin et al., 2013, Peck et al., 2013, Whitney, 2013, Scheiman et al., 1994, Scheiman et al., 2006, Chan et al., 2002, Regula et al., 2006, Yeomans et al., 2008, Bianchi, 1998, Bianchi, 2000, Hawkey et al., 2005, Desai et al., 2008, Bergmann et al., 1992). There is only one quality head-to-head trial, and it found no difference in efficacy between pantoprazole and omeprazole (Edmundson et al., 2016, Scheiman et al., 2006). Misoprostol has also been consistently shown to be effective compared with placebo (Coggon et al., 2013, Lezak, 2004, Wechsler, 1997, Donders et al., 2001, Donders et al., 2015, Rabin et al., 2005, Reid-Arndt et al., 2011, Miller et al., 2004, Greve et al., 2003, Greve et al., 2008) (Graham et al., 2002, Raskin et al., 1995) (Elliott et al., 1994, Chandrasekaran et al., 1991, Lanza et al., 1988, Jiranek et al., 1989, Donnelly et al., 2000, Medina Santillan et al., 1999, Koch et al., 2000). Relatively fewer studies have shown sucralfate to be effective compared with placebo (Mathias et al., 2002, Miglioli et al., 1996); H2 blockers appear more effective for treatment of duodenal than gastric mucosa (Leong et al., 2014, Walsh et al., 2016, Vernau et al., 2015) (Robinson et al., 1989, Robinson et al., 1991, Ehsanullah et al., 1988). There are relatively few quality trials comparing efficacy of the different classes of agents. Pantoprazole but not lansoprazole has been found modestly superior to misoprostol (Liedes et al., 2015, Wilbur et al., 2008, Stupnicki et al., 2003, Graham et al., 2002). No difference was found between famotidine and lansoprazole (Walker et al., 2009, Miyake et al., 2005). Misoprostol has been reported superior to ranitidine (Strong et al., 2005, Curtis et al., 2009, Miglioli et al., 1996, Raskin et al., 1995),

cimetidine (Langeluddecke et al., 2003, Lanza et al., 1988), and sucralfate (Rabin et al., 2005, Fisher et al., 2000, Agrawal et al., 1991, Lanza et al., 1988).

In short, while the evidence is not definitive, available quality evidence suggests proton pump inhibitors and misoprostol appear superior to H-2 blockers and sucralfate. While COX-2 selective agents have generally been recommended as either third- or fourth-line medications for routine use in osteoarthrosis patients, when there is a risk of gastrointestinal complications, they are often preferred. For patients at high risk of gastrointestinal bleeding, there is evidence that a combination of proton pump inhibitor plus COX-2 selective agent is efficacious (Ryan et al., 2005, Goldstein et al., 2006).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: sucralfate; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 1 article in PubMed, 0 in CINAHL, 0 in Cochrane Library, 804 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

H2 BLOCKERS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

H2-blockers are selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Moderate

Indications

NSAID use with either risk factors for GI bleeding (e.g., elderly, diabetes mellitus, rheumatoid arthritis), or ICU stay and concerns for gastric ulcers. May be needed for others at high risk of GI bleeding in the subacute and chronic stages.

Benefits

Eliminates increased risk of GI bleeding from NSAIDs. May reduce risk of stress ulcers.

Harms

Adverse effects of the proton pump inhibitor. Concerns for higher bacterial burden in the stomach with lack of low pH and thus increased risk of bacterial pneumonia from aspiration, making suggestions sucralfate or possibly H2 blockers may be preferable for that indication (Fohl et al., 2011, Herzig et al., 2009).

Frequency/Dose/Duration

Dose and frequency for proton pump inhibitors, sucralfate, and H2 blockers are as recommended by manufacturer. Duration is the extent of the NSAID therapy; use is at times permanent for those with recurrent bleeds or other complications.

Rationale

Risks of gastrointestinal events are also recommended for assessment, particularly including prior history of gastrointestinal bleeding and source, length of treatment, age, smoking, diabetes mellitus and other medical factors. Those with greater risk should be considered for treatment with acetaminophen, NSAID plus misoprostol, proton pump inhibitors (see below), or a COX-2 selective agent (see NSAIDs/acetaminophen evidence table) (Nelson et al., 2015, Echemendia et al., 2016, Townend et al., 2006, Snyder et al., 2014, Greve et al., 2006, McCusker PJ, 2003, Fenton et al., 2004, Garner et al., 2005, Berenbaum et al., 2005, Agrawal et al., 1999, Bocanegra et al., 1998, Melo Gomes et al., 1993).

Gastrointestinal adverse events are generally considered the most significant of the risks of NSAIDs. A large volume of high- and moderate-quality evidence consistently shows proton pump inhibitors are effective for prevention and or treatment of gastric and duodenal ulcers and erosions (Arbisi et al., 2011, Alkemade et al., 2015, Edmundson et al., 2016, Jones, 2016, Pape et al., 2016, Lange et al., 2015, Bolinger et al., 2013, Goodwin et al., 2013, Peck et al., 2013, Whitney, 2013, Scheiman et al., 1994, Scheiman et al., 2006, Chan et al., 2002, Regula et al., 2006, Yeomans et al., 2008, Bianchi, 1998, Bianchi, 2000, Hawkey et al., 2005, Desai et al., 2008, Bergmann et al., 1992). There is only one quality head-to-head trial, and it found no difference in efficacy between pantoprazole and omeprazole (Edmundson et al., 2016, Scheiman et al., 2006). Misoprostol has also been consistently shown to be effective compared with placebo (Coggon et al., 2013, Lezak, 2004, Wechsler, 1997, Donders et al., 2001, Donders et al., 2015, Rabin et al., 2005, Reid-Arndt et al., 2011, Miller et al., 2004, Greve et al., 2003, Greve et al., 2008) (Graham et al., 2002, Raskin et al., 1995) (Elliott et al., 1994, Chandrasekaran et al., 1991, Lanza et al., 1988, Jiranek et al., 1989, Donnelly et al., 2000, Medina Santillan et al., 1999, Koch et al., 2000). Relatively fewer studies have shown sucralfate to be effective compared with placebo (Mathias et al., 2002, Miglioli et al., 1996); H2 blockers appear more effective for treatment of duodenal than gastric mucosa (Leong et al., 2014, Walsh et al., 2016, Vernau et al., 2015) (Robinson et al., 1989, Robinson et al., 1991, Ehsanullah et al., 1988). There are relatively few quality trials comparing efficacy of

the different classes of agents. Pantoprazole but not lansoprazole has been found modestly superior to misoprostol (Liedes et al., 2015, Wilbur et al., 2008, Stupnicki et al., 2003, Graham et al., 2002). No difference was found between famotidine and lansoprazole (Walker et al., 2009, Miyake et al., 2005). Misoprostol has been reported superior to ranitidine (Strong et al., 2005, Curtis et al., 2009, Miglioli et al., 1996, Raskin et al., 1995), cimetidine (Langeluddecke et al., 2003, Lanza et al., 1988), and sucralfate (Rabin et al., 2005, Fisher et al., 2000, Agrawal et al., 1991, Lanza et al., 1988).

In short, while the evidence is not definitive, available quality evidence suggests proton pump inhibitors and misoprostol appear superior to H-2 blockers and sucralfate. While COX-2 selective agents have generally been recommended as either third- or fourth-line medications for routine use in osteoarthrosis patients, when there is a risk of gastrointestinal complications, they are often preferred. For patients at high risk of gastrointestinal bleeding, there is evidence that a combination of proton pump inhibitor plus COX-2 selective agent is efficacious (Ryan et al., 2005, Goldstein et al., 2006).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: H2 blocker; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 15,704 in CINAHL, 2,837 in Cochrane Library, 19,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

DEAMINO ARGININE VASOPRESSIN (DDAVP) (DESMOPRESSIN)

Desmopressin is an ADH analog aimed at decreasing urine output by increasing the activity of ADH [(639)].

DEAMINO ARGININE VASOPRESSIN (DDAVP) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Deamino arginine vasopressin (DDAVP) is recommended for treatment of diabetes insipidus. Otherwise, there is no recommendation for or against DDAVP for patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

DDAVP (Cabergoline) is recommended for treatment of diabetes insipidus (Bichet et al., 2016) but there is no recommendation for use in patients with TBI.

Frequency/Dose/Duration

Per manufacturer's recommendation.

Indications for discontinuation

Until not needed for treatment of diabetes insipidus.

Rationale

There are no quality studies of cabergoline specifically for treatment of TBI, and thus there is no recommendation. However, some patients do have indications for treatment of diabetes insipidus.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Deamino Arginine Vasopressin, desmopressin**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 12 articles in PubMed, 4 in CINAHL, 2 in Cochrane Library, 998 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

DEXTROMETHORPHAN

Dextromethorphan/quinidine has been used for treatment of pseudobulbar affect in adults with underlying neurological conditions [640, 641, 642].

DEXTROMETHORPHAN FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for the use of dextromethorphan in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Indications

Emotional dyscontrol accompanying TBI, pseudobulbar palsy.

Benefits

Purported improvement of control of emotions associated with TBI.

Harms

Sedation, fatigue, nausea, vomiting, constipation, diarrhea, dizziness, confusion.

Frequency/Dose/Duration

As per manufacturer's recommendation.

Rationale

Dextromethorphan has been studied for the treatment of traumatic brain injury (Hicks et al., 2020). Dextromethorphan is not invasive, has some adverse effects, and is low to moderate cost. There are no quality studies addressing the use of dextromethorphan for patients with TBI and thus there is no recommendation. Dextromethorphan also has other potential indications, and there is some evidence of potential efficacy of dextromethorphan/quinidine for treatment of pseudobulbar affect among patients with amyotrophic lateral sclerosis (Brooks WS, 2004) and multiple sclerosis (Panitch HS, 2006).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Dextromethorphan**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 4 articles in PubMed, 0 in CINAHL, 1 in Cochrane Library, 3,770 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article

considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ERYTHROPOIETIN

ERYTHROPOIETIN FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Erythropoietin is selectively recommended for the treatment of TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Acute severe TBI, especially for patients with elevated mortality risks.

Benefits

Reduced mortality at 6 months.

Harms

Allergic reactions, chills, rigors, fatigue, itch, rash, dizziness, headaches, dyspnea, wheezing, hives, edema, back pain, diarrhea, blood clots, hypertension, stroke, myalgias, arthralgias, polycythemia.

Frequency/Dose/Duration

Trials have used significantly different dosing regimens, including the following:

- EPO 40,000 IU IV within 6 hrs of injury (Nirula R, 2010)
- EPO 500 IU/kg IU IV within 6 hrs of injury (Robertson et al., 2014)
- EPO 40,000 IU SQ within 24 hrs of injury and then up to 3x/week (Nichol et al., 2015)
- EPO 40,000 IU SQ per week for up to 3 weeks or until discharge from ICU (Skrifvars et al., 2019)
- EPO 30,000 IU SQ within 24 hrs of injury and then weekly for up to 3 weeks or until discharge from ICU (Knott, 2018)
- EPO 40,000 SQ within 24 hrs and at days 8 and 15 (Hellewell et al., 2018)
- EPO 6,000 IU SQ at 2 hrs, and 3, 6, 9, and 12 days after admission (Li et al., 2016)

Indications for discontinuation

Completion of a course, adverse effects.

Rationale

Most higher-quality trials of erythropoietin have reported a lack of short-term efficacy, but with a possible reduction in mortality at 6 months (Nirula R, 2010, Abrishamkar, 2012, Robertson et al., 2014, Aloizos et al., 2015, Li et al., 2016, Bai, 2017, Talving, 2012, Skrifvars et al., 2019, Nichol et al., 2015, Hellewell et al., 2018, Knott, 2018). Multiple systematic reviews with meta-analyses have also similarly reported no reductions for in-hospital mortality, but 32-35% reduced mortality at 6 months (Lee et al., 2019, Katiyar et al., 2020, Li et al., 2022, Liu et al., 2020). Erythropoietin is minimally invasive, has modest adverse effects, and is costly, with the higher-quality studies showing reductions in the 6-month mortality rate. Therefore, it is selectively recommended. There is no quality evidence for improvements in global or neurological function.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Erythropoietin; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 52 articles in PubMed, 0 in CINAHL, 18 in Cochrane Library, 20,000 in Google Scholar, and 0 from other sources. We considered for inclusion 21 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 21 articles considered for inclusion, 17 randomized trials and 4 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MIGRAINE MEDICATIONS

The International Headache Society classifies posttraumatic headache (PTH) as “headache attributable to Injury to the head” [(643)]. In contrast to the most common primary headache disorders (migraine and tension-type headache), PTH is an acquired headache, and therefore a secondary headache. The most common phenotypes associated with PTH are migraine/probable migraine, tension-type headache, or both. The diagnosis of PTH is dependent upon the close temporal relationship between injury and the onset of headache, typically within 7 days. Individuals who have a prior history of migraine are at higher risk of

posttraumatic headaches and prolonged symptoms after concussion. Risk factors for PTH include a previous history of headache, female sex, vertigo, less severe injury, anxiety, and depression [644, 645, 1000].

When a new headache occurs for the first time in close temporal relation to trauma to the head, it is coded as a secondary headache attributed to the trauma or injury. When a pre-existing headache becomes substantially worse in close temporal relation to an injury, both the initial headache diagnosis and the diagnosis of PTH should be given [643].

The symptoms of post/concussion syndrome and migraine can overlap (e.g., headache, dizziness, nausea, sensitivity to light or sound, neck pain and difficulty functioning) [644, 646, 647]. When postconcussion symptoms do not resolve or increase over time, alternative diagnosis should be considered [648, 649, 1001]. The World Health Organization has identified migraine as one of the most disabling diseases in the world [650, 651]. Migraine is an autosomal disorder that affects approximately one in seven individuals worldwide and is frequently undiagnosed or misdiagnosed: approximately half of patients with migraine are undiagnosed [652] and one-third are misdiagnosed with cervicogenic headache [653]. If PTH does not resolve or worsens over time, then evaluation for an underlying primary headache disorder (migraine, TTH) or risk factors of such (e.g., anxiety, depression, dizziness, early childhood motion sickness, or family history of headache, depression, or substance use) may identify a treatable, primary headache disorder. When both a primary headache disorder and secondary headache disorder are diagnosed, each diagnosis should be recorded.

There are few controlled studies assessing diagnosis and treatment of PTH. As a result, PTH should be treated according to the phenotype that is most closely resembles (typically migraine variant or tension type headache variant. Treatment involves the use of preventive and abortive medications based on the underlying headache phenotype (e.g., use of medications shown to be effective for migraine for migraine phenotypical headaches). Of these, nutraceutical therapies (magnesium, riboflavin) and the triptans (eletriptan, rizatriptan) are effective and readily accessible [645]. There are some differences in the treatment of patients with PTH: for example, antiseizure medications such as topiramate and valproic acid and tricyclic antidepressants are advised for primary migraine headache, but they should be used with caution with patients with PTH who endorse cognitive symptoms [645]. NSAIDs can be effective to abort headache, but judicious use is advised to avoid precipitating medication overuse headache [654, 655]. Narcotic medications and butalbitals should be avoided for nearly all headache phenotypes because of the associated risk of medication overuse headache [656]. The American Headache Society recommends the CGRP antagonists (gepants and monoclonal antibodies) as first-line treatment for the primary headache disorder, migraine [657]. However, evaluation of the efficacy of the CGRP antagonists in the secondary headache disorder, PTH-migraine variant, is ongoing [645, 658]. Some evidence has also been reported regarding efficacy of interventional procedures (see other recommendations below).

Symptoms in PTH can be aggravated by physical or cognitive exertion. Therefore, therapy designed to avoid exacerbation of symptoms (submaximal threshold) with gradual progression and behavioral techniques can be effective in treating PTH or limiting progression of symptoms.

Recognition and prompt treatment of PTH can prevent the development of a chronic headache disorder, resolve symptoms that mimic concussion, and mitigate the risk of progression to medication overuse headache.

MIGRAINE HEADACHE MEDICATIONS FOR POST-TBI MIGRAINE HEADACHES (TRIPTANS, ERGOT ALKALOIDS, GEPANTS, CGRP RECEPTOR ANTAGONISTS, DITANS)

Recommended

Migraine headache medications, including triptans, ergot alkaloids, gepants / CGRP receptor antagonists (e.g., ubrogepant, rimegepant, zavegepant) and ditans (lasmiditan), are recommended for treatment of post-TBI migraine headaches.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Migraine headache attributable to traumatic injury to the head.

Frequency/Dose/Duration

Per manufacturer's recommendations.

Indications for discontinuation

Adverse effects, intolerance, adverse effects, resolution of headaches.

Rationale

There are no quality trials specifically for treating patients with TBI. However, these medications have approved indications for treatment of migraines (Holland et al., 2012, Silberstein et al., 2012). Thus, they are recommended for treatment of patients with TBI based on valid neuropsychometric testing that is consistent with the natural history of the underlying neurological disease (Strauss E, 2006, Tariq SH, 2006).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Ergot Alkaloids OR Triptans; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 44 articles in PubMed, 3 in CINAHL, 2 in Cochrane Library, 1,010 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MOOD STABILIZERS

Structural brain changes, cognitive and functional decline, and poor treatment response are all characteristics of neuropsychiatric disorders. Mood stabilizers such as lithium are theorized to upregulate numerous neuroprotective pathways in order to inhibit the functional and structural decline of the brain [(659)].

MOOD STABILIZERS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation regarding mood stabilizers for treatment of patients with TBI. There may be other indications for treatment with these agents (see also the ACOEM Depressive Disorders and Anxiety Disorders Guidelines).

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies for the use of mood stabilizers to treat patients with TBI. Lithium may be indicated for treatment of mania and bipolar disorders that are beyond the scope of this guideline (see also the ACOEM Depressive Disorders and Anxiety Disorders Guidelines). Thus, there is no recommendation for or against the use of mood stabilizers for treatment of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Mood stabilizers; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 19 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 18300 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

NMDA RECEPTOR ANTAGONISTS

Excitatory amino acid inhibitors prevent the reuptake of excitatory neurotransmitters, aspartate and glutamate, by interfering with excitatory amino acid transporters [583, 624, 625, 660-662]. After experiencing a TBI, ionic imbalances in brain tissue purportedly result in excitotoxic episodes that are thought to potentially lead to neuronal death [660, 661].

Memantine is an N-methyl-D-aspartate (NMDA)-receptor antagonist. It works by blocking excess activity from glutamate and "may" reduce symptoms associated with Alzheimer's disease [663] or Parkinson's disease or other types of dementia [664].

Some inhibitory drugs, such as ketamine and dexanabinol, have also been included in this class and have been suggested to reduce mean arterial pressure, without resulting in increased intracranial pressure [583, 625].

EXCITATORY AMINO ACID INHIBITORS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against excitatory amino acid inhibitors.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are four moderate-quality trials assessing excitatory amino acid inhibitors for treatment of patients with acute, severe TBI (Yurkewicz et al., 2005, Lepeintre et al., 2004, Morris et al., 1999). One pilot study suggested that gacyclidine may be beneficial at high doses (Lepeintre et al., 2004). These medications are not invasive, have adverse effects, but lack evidence of efficacy other than a potentially promising pilot study of gacyclidine. Thus, there is no recommendation for or against these medications.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Excitatory amino acid inhibitors; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 8 articles

in PubMed, 0 in CINAHL, 6 in Cochrane Library, 17,000 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MEMANTINE FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Memantine is selectively recommended for the treatment of patients with TBI in the subacute or chronic phases having objective evidence of cognitive deficits.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Memantine is selectively recommended for the treatment of patients with TBI having objective evidence of cognitive deficits in the subacute or chronic phases of TBI. A 1-month trial is recommended with documentation of improvements in objective measures of cognitive impairment before consideration of ongoing treatment.

Benefits

Modest improvements in memory, forgetfulness, confusion.

Harms

Adverse effects include swelling, weight gain, weight loss, blurred vision, nervousness, drowsiness, headache, dizziness, heart rate abnormalities, dyspnea, constipation.

Frequency/Dose/Duration

Memantine 5mg/day up to 10mg twice a day in immediate-release form or 7mg/day up to 28mg/day for extended-release form.

Indications for discontinuation

Intolerance, sufficient resolution of symptoms, lack of benefits and/or non-compliance.

Rationale

One low-quality trial found improvements for patients with TBI after a short-duration treatment with memantine (Mokhtari et al., 2018). A systematic review found mixed results among the RCT evidence (Khan et al., 2021). Because there are no quality studies of memantine for TBI and it has evidence of efficacy for treatment of cognitive impairments related to Alzheimer's disease, memantine is selectively recommended for the treatment of patients with TBI having objective evidence of cognitive deficits in the subacute or chronic phases of TBI. A 1-month trial is recommended with documentation of improvements in objective measures of cognitive impairment before consideration of ongoing treatment.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Memantine; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 13 articles in PubMed, 0 in CINAHL, 5 in Cochrane Library, 3490 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 1 randomized trial and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

NSAIDS

Non-steroidal anti-inflammatory (NSAIDs) have been used for treatment of traumatic brain injuries, although mostly for febrile control [665, 666, 667]. A few studies reviewed potential NSAID use for intracerebral pressure control [667, 668]. Some have theorized that NSAIDs may be helpful in neuroregenerative processes [669], and one trial in mice found evidence of reduced inflammatory responses among those mice treated with ibuprofen although no differences in their cognitive-maze test [670].

NSAIDS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against NSAIDs for treatment of TBI. There are other indications for patients such as headache, febrile control, and musculoskeletal pain.

Strength of evidence No Recommendation, Insufficient Evidence (I)

Level of confidence Low

Rationale

There are no quality placebo-controlled trials evaluating the use of NSAIDs for treatment of TBI. A Cochrane review found no quality evidence of efficacy of NSAIDs to reduce intracranial pressure (Martín-Saborido et al., 2019). Thus, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Non-Steroidal Anti-Inflammatory Agents and NSAIDS **;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 55 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 18,800 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

OTHER MEDICATIONS

Magnesium is a cofactor in cellular energy metabolism and protein synthesis and is a calcium channel blocker. Magnesium increases cardiac output and cerebral blood flow. It has been used for treatment of patients with TBI [(671)]. Progesterone has been thought to have neuroprotective effects and has been used for treatment of patients with TBI [(672, 673, 674, 675, 676, 677)]. Bromocriptine is a dopamine receptor agonist that affects D2 and partially affects D1 receptors. D2 sites reportedly are involved in patients with head injuries in controlling NP and NBH problems, and D2 sites affect the nigrostriatal region. When head injuries are severe and diffuse in nature, bromocriptine is purportedly beneficial [(556, 678, 679)] and [(557)].

Cyclosporine has been used for treatment of patients with TBI [(680, 681, 682, 683, 684)]. It has been suggested that cyclosporine is an immunosuppressant which attenuates mitochondrial dysfunction following TBI thus acting as a neuroprotective agent [(684)]. Donepezil has been used for treatment of TBI, particularly for targeting cognitive function such as memory [(685, 686, 687, 688, 689)]. Methylphenidate (MP) has been used to treat complications associated with traumatic brain injury (TBI) such as arousal, initiation, and attention problems [(690)], as well as cognitive and behavioral impairments in some patients with TBI [(691, 692, 693)]. Modafinil is primarily used for treatment of narcolepsy and hypersomnolence [(694)], although it has been used for other causes of somnolence including TBI.

MAGNESIUM FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Magnesium is not recommended for patients with TBI, other than for patients with magnesium deficiency.

Strength of evidence Not Recommended, Insufficient Evidence (I)
Level of confidence Low

Rationale

There is one high-quality trial among patients with acute, moderate to severe TBI suggesting lack of efficacy for treatment of patients with moderate to severe TBI (Temkin et al., 2007). The other trial was only partially completed and was low quality (Van Norden et al., 2005). There are multiple other trials (Dhandapani et al., 2008, Rehmani et al., 2022, Sohn et al., 2022, Zhao et al., 2016). A systematic review with meta-analysis reported a lack of efficacy for most outcome measures, although the GCS was better with magnesium (Lyons et al., 2018). With one high-quality trial suggesting lack of efficacy, magnesium is not recommended for the treatment of patients with TBI, absent evidence of magnesium nutritional deficiency.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Magnesium, Magnesium Sulfate; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 4 articles in PubMed, 1 in CINAHL, 2 in Cochrane Library, 15900 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 6 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 6 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

PROGESTERONE FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Progesterone is not recommended for patients with TBI.

Strength of evidence Strongly Not Recommended, Evidence (A)
Level of confidence High

Rationale

Progesterone has been studied for the treatment of mostly moderate to severe traumatic brain injury patients (Pan et al., 2019, Begemann et al., 2020, Nasre-Nasser et al., 2022). There are two high-quality, sizable trials of progesterone for patients with moderate to severe, acute TBI, with neither showing benefits (Wright et al., 2014, Skolnick et al., 2014) and one showing increased risk of phlebitis (Wright et al., 2014). Two smaller-sized trials had suggested some potential benefits (Xiao et al., 2008, Wright et al., 2007). There are multiple other trials (Aboukhabar, 2017, Abdoli et al., 2019, Goldstein, 2017, Zhang et al., 2020, Korley et al., 2021, Merck et al., 2019, Mofid et al., 2016, Shaalan, 2019, Sinha et al., 2017, Soltani et al., 2017). A Cochrane review concluded there was not evidence that progesterone resulted in reduced mortality and/or disability (Ma et al., 2016), which is a similar result reported in most other systematic reviews (Bazgir et al., 2021, Zeng et al., 2015). Progesterone is either not invasive or minimally invasive, has apparent risks of phlebitis and thrombophlebitis, is low cost, but is not shown to be effective; thus, it is not recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Progesterone**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 21 article in PubMed, 0 in CINAHL, 11 in Cochrane Library, 23,800 in Google Scholar, and 0 from other sources†. We considered for inclusion 9 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 6 from Google Scholar, and 2 from other sources. Of the 17 articles considered for inclusion, 10 randomized trials and 7 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BROMOCRIPTINE FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against bromocriptine for treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are three small, moderate-quality crossover trials with conflicting results regarding efficacy (Whyte et al., 2008, McDowell et al., 1998, McAllister et al., 2011). The studies were of mostly moderate to severe and subacute to chronic TBI patients, but there is no clear pattern of efficacy based on one of those particular categories. Thus, there is no recommendation for or against bromocriptine in the treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: bromocriptine, traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 2040 in Google Scholar, and 2 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 6 from Google Scholar, and 3 from other sources. Of the 10 articles considered for inclusion, 6 randomized trials and 4 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CYCLOSPORINE FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against cyclosporine for treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are few trials of cyclosporine for purposes of treating acute, severe TBI. Most studies are dosing or pharmacokinetic studies. There is one moderate-quality trial for treatment of patients with TBI and found a nonsignificant trend suggesting improved functional outcomes (Hatton et al., 2008). However, without clear evidence of efficacy, there is no recommendation until additional studies with sufficient power are available.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Cyclosporine; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 9 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 3,730 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

DONEPEZIL FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Donepezil is recommended for patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Benefits

Improvements in memory and attention.

Harms

Bowel frequency and incontinence (Zhang et al., 2004).

Frequency/Dose/Duration

Trial was of 10 weeks duration (Zhang et al., 2004). It is unclear if longer duration has any added benefits.

Rationale

There is one moderate-quality trial suggesting modest efficacy among patients with subacute or chronic TBI for memory impairments (Zhang et al., 2004). A second trial lacked placebo control and reported comparable efficacy between donepezil, galantamine, and rivastigmine (Tenovuo, 2005). A meta-analysis found donepezil was effective for memory loss related to TBI (van der Veen et al., 2024) and another systematic review drew comparable conclusions (Florentino et al., 2022). Donepezil is not invasive, has low adverse effects, and is thus recommended for cognitive function.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Donepezil; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 5 articles in PubMed, 1 in CINAHL, 1 in Cochrane Library, 9,310 in Google Scholar, and 3 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 0 randomized trials and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

METHYLPHENIDATE FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Methylphenidate is recommended for patients with TBI with cognitive deficits.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

Acute to subacute TBI with impaired cognitive functioning. May be reasonable to trial in those with chronic TBI who exhibit cognitive problems.

Benefits

Improved memory, attention, cognition.

Harms

Long term safety and risks have not been well determined in TBI patient populations (Barnett et al., 2020). Difficulty sleeping, decreased appetite, blunted affect, nervous habits and mannerisms, and obsessive thinking. Infrequent hypertension and tachycardia (Alban et al., 2004).

Frequency/Dose/Duration

Six weeks (Whyte et al., 2004). Longer duration may be indicated for ongoing deficits, provided there are also ongoing cognitive improvements.

Indications for discontinuation

Tachycardia, hypertension, excessive or intolerable harms including difficulty sleeping, decreased appetite, blunted affect, nervous habits and mannerisms, and obsessive thinking

Rationale

Nearly all placebo-controlled RCTs, and all of the higher-quality trials, have reported improvements in cognitive function with methylphenidate treatment (Willmott et al., 2009, Zhang et al., 2017, Whyte et al., 2004, McDonald et al., 2017, Kim et al., 2006, Jenkins et al., 2019, Gualtieri et al., 1988, Johansson et al., 2014, Lee et al., 2005, Mooney et al., 1993). Most of the studies enrolled chronic, moderate to severe TBI patients. Two high-quality, placebo-controlled studies showed evidence of efficacy: a randomized crossover trial of 2-weeks duration showed improved information processing speed (Willmott et al., 2009, Willmott et al., 2009), whereas a 30-week RCT also showed efficacy for mental fatigue and cognitive functioning (Zhang et al., 2017). Moderate-quality trials also suggest efficacy, including a 6-week trial showing improvements in word-list learning, nonverbal learning, auditory working memory, and divided attention (McDonald et al., 2017). Another 6-week, moderate-quality treatment trial suggested improved cognitive processing and attention (Whyte et al., 2004). One study showed some benefit with even a single dose, although this study had a small sample size (Kim et al., 2006). Systematic reviews have drawn similar conclusions of evidence of efficacy (Barnett et al., 2020, Chien et al., 2019, Huang et al., 2016).

Methylphenidate is not invasive, has relatively low adverse effects, is not costly, and is recommended for treatment of patients with TBI with cognitive and attentional deficits.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: methylphenidate; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 41 article in PubMed, 7 in CINAHL, 29 in Cochrane Library, 6,920 in Google Scholar, and 0 from other sources†. We considered for inclusion 8 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 12 articles considered for inclusion, 9 randomized trials and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MODAFINIL FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against modafinil for patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are three moderate-quality studies on Modafinil. One study (Kaiser et al., 2010) showed some improvement in EDS and ability to stay awake but not in posttraumatic fatigue. Another study (Jha et al., 2008) showed no benefit when compared to placebo. Thus, there is no recommendation for or against modafinil or armodafinil for patients with TBI, although it may be indicated for the treatment of narcolepsy and hypersomnolence (Talsky, 2011).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Modafinil, Provigil; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 6 articles

in PubMed, 2 in CINAHL, 0 in Cochrane Library, 1860 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 randomized trial and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

PIRACETAM

Piracetam is a derivative of gamma-aminobutyric acid (GABA) and has been suggested to restore cellular membrane fluidity. At the neuronal level, Piracetam modulates cholinergic and glutamatergic transmitter systems and is thought to have neuroprotective and anticonvulsant properties. It has been used to treat cognitive disorders and dementia [695].

PIRACETAM FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against use of piracetam for treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies of piracetam. Thus, there is no recommendation for or against its use for TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: piracetam; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 16 articles in PubMed, 0 in CINAHL, 1 in Cochrane Library, 710 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are

reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

RIVASTIGMINE

Physostigmine and rivastigmine are cholinesterase inhibitors that have been suggested to improve cholinergic function, memory retention and cognitive function in patients with TBI [696-698]. Scopolamine alternatively has been associated with memory impairments in some experimental studies [699-701], providing some rationale for physostigmine.

RIVASTIGMINE AND PHYSOSTIGMINE FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against rivastigmine or physostigmine for treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are several studies using rivastigmine for TBI. One trial with two reports found overall negative results driven by negative results among those with mild TBI, but suggested that among those with moderate to severe TBI there were improvements (Silver et al., 2006, Silver et al., 2009). Other studies found lack of efficacy (Brawman-Mintzer et al., 2021), modest benefits (Tenovuo et al., 2009), or no advantage over donepezil or galantamine (Tenovuo, 2005). Adverse drug reactions are high (Tenovuo et al., 2009). There are two moderate-quality studies from several decades ago, with neither showing clear benefit of physostigmine (Cardenas et al., 1994, Levin et al., 1986).

Rivastigmine and physostigmine are not invasive, have considerable adverse effects, are moderately costly, and have conflicting evidence of efficacy in patients with moderate to severe TBI. Thus, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Rivastigmine OR Exelon; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 12 articles in PubMed, 0 in CINAHL, 3 in Cochrane Library, 2,990 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from

Cochrane Library, 0 from Google Scholar, and 0 from other sources. One randomized trial and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SEDATIVES, SEDATIVE HYPNOTICS, AND OPIOIDS

A variety of agents in this classification have been used to treat patients with TBI, primarily for purposes of inducing and/or controlling sedation, including propofol [602, 603, 604, 702], ketamine [583, 703], midazolam [602-604, 703], fentanyl [703-706], remifentanil [705], sufentanil [583, 706], alfentanil [706], dexmedetomidine [702], morphine [704, 705]. These have been used in hospital settings, and thus they are beyond the scope of this guideline.

For guidance on Opioids Use, see Opioids Guideline.

SUBSTANCE P ANTAGONISTS (NEUROKININ 1 RECEPTORS)

Substance P antagonists are non-peptidic antagonists which have recently emerged as a class of drugs with antidepressant activity but potentially less adverse effects [707, 708]. Substance P has been determined to directly result in neuronal death. Limiting the release of Substance P has been linked to a decrease in cerebral edema and increased functional outcomes post TBI [623].

SUBSTANCE P ANTAGONISTS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against substance P antagonists for the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies of substance P antagonists and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Neurokinin-1 Receptor Antagonists OR "Substance P antagonists" OR Aprepitant; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials,

randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 1 article in PubMed, 0 in CINAHL, 17 in Cochrane Library, 11,800 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

TRANEXAMIC ACID

Tranexamic acid aids in reducing blood loss, or intracranial bleeding, associated with traumatic brain injury without increased occlusive events [709, 710, 711, 712].

TRANEXAMIC ACID FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for tranexamic acid, which is typically used to attempt to prevent further bleeding among patients with acute, severe TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

One large, high-quality study suggested that tranexamic acid reduced the risk of death by an absolute value of 1.5% (14.5% vs. 16.0%) if given within 3 hours (Roberts et al., 2013). One large, multicenter trial found no reduction in mortality of disability at 6 months (Rowell et al., 2020). There are other studies with much smaller sample sizes, one of which is borderline significant (Perel et al., 2012, Yutthakasemsunt et al., 2013). Multiple systematic reviews with meta-analyses conflict, with some concluding that tranexamic acid is associated with a reduced risk of intracranial hemorrhage expansion/growth events and modestly reduced mortality (Alhelaly et al., 2019, Chen H, 2019, July et al., 2020, Karl et al., 2022, Weng et al., 2019, Zhang et al., 2024), while other reviews conclude the effect on mortality and meaningful outcomes is not significant (Lawati et al., 2021, Sarhan et al., 2024, Yokobori et al., 2020, Zhang et al., 2024). Differences in outcomes may be related to timing of administration.

Tranexamic acid is minimally invasive, has adverse effects, is costly, and has significantly conflicting evidence of efficacy. Thus, there is no recommendation. (See also the ACOEM Eye Guideline for use of tranexamic acid for traumatic hyphema.)

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Tranexamic acid; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 180 articles in PubMed, 9 in CINAHL, 55 in Cochrane Library, 6,320 in Google Scholar, and 0 from other sources†. We considered for inclusion 24 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 28 articles considered for inclusion, 16 randomized trials and 12 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ALLIED HEALTH INTERVENTIONS

ACUPUNCTURE

Acupuncture has been used to treat some patients with traumatic brain injury [713, 714], muscle spasticity [713], insomnia [715], and cervical disorders. Cervical spine disorders are likely the most common indication for acupuncture among patients with TBI. The reader is referred to the ACOEM Cervical and Thoracic Spine Disorders guideline for recommendations on acupuncture.

BIOFEEDBACK

BIOFEEDBACK FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of biofeedback in the treatment of patients with TBI. (See also the ACOEM Chronic Pain Guideline.)

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Biofeedback has been studied for the treatment of traumatic brain injury (Bonn et al., 2021, Talbert et al., 2023, Kim et al., 2018, Dubienski, 2016). There are few quality studies assessing biofeedback for treatment of TBI. One moderate-quality study of severe TBI patients with a wait-list control bias reported that while most primary measures were negative, there were fewer sleep disturbances and reduced mood valence and depression

with biofeedback (Wearne et al., 2021). Another moderate-quality study of mild TBI patients suggested that compared with a psychoeducation control group, there were improvements in executive function, information processing, verbal memory, emotional neuropsychological functioning, and heart rate variability (Lu et al., 2023).

There are multiple low-quality studies, many of which also have small sample sizes and/or were pilot studies (Bonn et al., 2021, Campbell et al., 2022, Handiru et al., 2022, Veerubhotla et al., 2021). A systematic review regarding heart rate variability biofeedback treatment concluded that "effectiveness is unclear due to poor-to-fair study quality, and potential publication bias" (Talbert et al., 2023).

Biofeedback is not invasive, has no adverse effects, is low cost, but has quite limited quality evidence of treatment efficacy. Thus, there is no recommendation for treatment of TBI. There may be other indications for biofeedback (see the ACOEM Chronic Pain Guideline).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Biofeedback; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 36 articles in PubMed, 8 in CINAHL, 4 in Cochrane Library, 10,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 10 articles considered for inclusion, 9 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

DEEP THALAMIC STIMULATION

DEEP THALAMIC STIMULATION FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of deep thalamic stimulation in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies assessing deep thalamic stimulation for treatment of TBI. A systematic review found only small studies involving a total of 10 patients (Rezaei Haddad et al., 2019, Schiff et al., 2023). Deep thalamic stimulation is not invasive, has no adverse effects, is low cost, has no quality evidence of treatment efficacy, and thus there is no recommendation for treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Deep thalamic stimulation OR DBS; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 36 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 36 articles, 0 in CINAHL, 6 in Cochrane Library, 16,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 1 diagnostic study and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ELECTRICAL STIMULATION

Functional electrical stimulation [716] uses a stimulator to activate skeletal muscle to accomplish a functional goal [717]. FES bypasses the injured spinal cord and applies electrical pulses to peripheral motor neurons that elicit or, in part, mimic action potentials to induce distal muscles to contract [718].

Neuromuscular electrical stimulation (NMES) is a therapeutic procedure used to strengthen muscle groups with preserved motor innervation [719-722]. NMES refers to the electrical stimulation of an intact lower motor neuron (LMN) to stimulate paralyzed or paretic muscles, providing a functional or therapeutic benefit [723].

FUNCTIONAL ELECTRICAL STIMULATION FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Functional electrical stimulation is not recommended for the treatment of patients with TBI.

Strength of evidence Not Recommended, Evidence (C)
Level of confidence Low

Rationale

There are only three quality and one low-quality study assessing functional electrical stimulation for treatment of TBI, and patient severity appears to have been severe (de Sousa, 2016, Leung et al., 2014, Lairamore et al., 2014, Peri et al., 2001). Only the low-quality study showed trends towards efficacy without statistical significance. Functional electrical stimulation is not invasive or minimally invasive, has negligible adverse effects, is moderate to high cost in aggregate, but has evidence suggesting lack of efficacy. Therefore, FES is not recommended for treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Functional electrical stimulation, FES; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 5 articles in PubMed, 1 in CINAHL, 14 in Cochrane Library, 4900 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

NEUROMUSCULAR ELECTRICAL STIMULATION (NMES) FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of neuromuscular electrical stimulation (NMES) in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Quality studies reported of NMES appear to have been of severe TBI patients. The highest-quality study of NMES found a lack of efficacy for chronic urinary retention (Zhang et al.,

2019). Three other quality studies assessing NMES for the treatment of TBI conflict, showing improved swallowing function (Terre et al., 2015), no improvement (Beom et al., 2015), and some improvements in the rectus femoris in ICU patients (Vieira et al., 2023). A low-quality trial suggested efficacy (Alon et al., 1998). Neuromuscular electrical stimulation is not invasive, has low adverse effects, and is moderate to high cost in aggregate. However, because it has substantially conflicting quality evidence of treatment efficacy, there is no recommendation for treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Neuromuscular electrical stimulation OR NMES; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 12 articles in PubMed, 3 in CINAHL, 14 in Cochrane Library, 12,600 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 3 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

HYPERBARIC OXYGEN

HYPERBARIC OXYGEN THERAPY FOR MILD TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Hyperbaric oxygen therapy is not recommended for the treatment of patients with mild TBI.

Strength of evidence Not Recommended, Evidence (C)
Level of confidence Low

Rationale

Hyperbaric oxygen therapy has been studied for mild traumatic brain injury (Crawford et al., 2017, Hawkins et al., 2017, Hart et al., 2019, Harch, 2022, Raj et al., 2024). One trial of HBO for treatment of chronic postconcussive symptoms suggested some subjective improvements at up to 6 months, but these improvements did not persist at 12 months and the objective measures were negative at all time periods (Weaver et al., 2018, Hart et al.,

2019). The next highest quality studies all showed negative results of HBO for treatment of mild TBI/post-concussive symptoms (Miller et al., 2015, Wolf et al., 2012, Cifu et al., 2014, Liu et al., 2023). One sham-controlled trial of chronic mTBI found improved sleep measures, although durability was waning at 6 months (Weaver et al., 2018). Another crossover trial with a no treatment control period showed improvements in subjective measures but not most of the objective measures (Harch et al., 2020).

There are multiple low-quality and small sample size studies (Oley et al., , Ren et al., 2023, Shandley et al., 2017, Wolf et al., 2015, Wetzel et al., 2019, Lu et al., 2021, Gupta, 2019). Systematic reviews drew disparate conclusions that include: (1) evidence of improvements in symptoms for mild TBI (Harch, 2022); "mixed results, " "potential benefits for acute TBI" and "limited efficacy of HBOT for chronic traumatic brain injury" (Raj et al., 2024); "no better than sham treatment" (Crawford et al., 2017). Problems noted in meta-analyses include differences in outcome measures used, and variations in compression, decompression and pressure used. According to (Hart et al., 2019), "A definitive clinical trial, with an appropriate control group, should be considered to identify the optimal HBO2 dosing regimen. "

Hyperbaric oxygen therapy is not invasive, usually has minimal adverse effects, is high cost, and has no objective evidence of efficacy. Furthermore, the purported improvements in subjective outcomes are not durable. Therefore, HBO is not recommended for the treatment of mild TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Hyperbaric oxygenation, Hyperbaric Oxygen Therapy, HBO, HBOT; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 59 articles in PubMed, 9 in CINAHL, 3 in Cochrane Library, 5680 in Google Scholar, and 0 from other sources†. We considered for inclusion 8 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 9 from Google Scholar, and 0 from other sources. Of the 17 articles considered for inclusion, 12 randomized trials and 5 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

HYPERBARIC OXYGEN THERAPY FOR MODERATE TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation regarding hyperbaric oxygen therapy for treatment of moderate TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Moderate

Rationale

Hyperbaric oxygen therapy has been studied for the treatment of moderate traumatic brain injury (Wolf et al., 2015, Lu et al., 2021). However, there is no quality evidence on the use of hyperbaric oxygen for moderate TBI. Thus, there is no recommendation for treatment of moderate TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Hyperbaric Oxygenation OR HBOT; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 77 articles in PubMed, 16 in CINAHL, 31 in Cochrane Library, 6,190 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 3 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

HYPERBARIC OXYGEN THERAPY FOR SEVERE TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Hyperbaric oxygen therapy is selectively recommended for the treatment of patients with severe TBI, although it is often limited by access to resources.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

Acute severe head injury (Glasgow Coma Scale score of 9 or less) admitted to a Level I trauma center in the highest quality study showing efficacy (Rockswold et al., 1992).

Benefits

Improved outcomes, earlier improvements in Glasgow Coma Score. Reduced mortality in one study with randomization within 24 hrs. of severe TBI (Rockswold et al., 2013).

Harms

Negligible.

Frequency/Dose/Duration

100% oxygen to 1.5 atm absolute (ATA) at a rate of 1 psi/min for 60 minutes every 8 hours for 2 weeks or until brain dead or could consistently respond to commands (Rockswold et al., 1992).

Indications for discontinuation

Brain dead, able to consistently respond to commands (Rockswold et al., 1992).

Rationale

Hyperbaric oxygen therapy has been studied for the treatment of severe traumatic brain injury (Daly et al., 2018). Three moderate-quality trials among patients with severe TBI found significant improvements in mortality in the HBO group (Rockswold et al., 2010, Ren et al., 2001, Peri et al., 2001). A systematic review concluded that HBO "has the potential to be the first significant treatment in the acute phase of severe TBI" (Daly et al., 2018).

Hyperbaric oxygen therapy is not invasive, usually has minimal adverse effects, is high cost, has evidence of treatment efficacy for severe TBI, and is recommended for those patients, although it is often limited by access to resources.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Hyperbaric Oxygenation HBOT; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 143 articles in PubMed, 16 in CINAHL, 66 in Cochrane Library, 8010 in Google

Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

HYPERVENTILATION

HYPERVENTILATION FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Hyperventilation is selectively recommended for the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Selectively recommended for brief control of severe TBI with increased intracranial pressure (usually >20mmHg), or perfusion pressure <70mmHg until other more effective measures may take effect. Addition of tromethamine may reduce adverse effects.

Benefits

Improved control of intracranial pressure, which may improve survival and neurological outcomes.

Harms

Respiratory alkalosis, seizures, muscle spasms.

Frequency/Dose/Duration

Use until more effective measures are in place.

Indications for discontinuation

Perfusion pressure and/or intracranial pressure normalized. May be discontinued after other measures effective.

Rationale

Hyperventilation has been historically used for TBI and empirically reduces intracranial pressure on a short-term basis. Because this treatment has long been in place, the size and quality of the evidence base is somewhat limited. Nevertheless, there are no quality studies showing efficacy of Hyperventilation for treatment of TBI. Hyperventilation is not invasive, has multiple adverse effects, is high cost, and has empirical evidence of short term efficacy for treatment of TBI. Thus, it is selectively recommended for treatment of increased intracranial pressure pending efficacy of more effective measures.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Hyperventilation; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 1 article in PubMed, 1 in CINAHL, 0 in Cochrane Library, 2 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

INDUCED HYPOTHERMIA

INDUCED HYPOTHERMIA FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Induced hypothermia is not recommended for the treatment of patients with TBI.

Strength of evidence Not Recommended, Evidence (C)
Level of confidence Moderate

Rationale

There are multiple moderate-quality studies assessing the utility of induced hypothermia for treatment of TBI (Harris et al., 2009, Andrews et al., 2015, Clifton et al., 1993, Clifton et al., 2011, Clifton et al., 2012, Maekawa et al., 2015, Mayer et al., 2004, Liu et al., 2006, Marion et al., 1993, Marion et al., 1997, Qiu et al., 2007, Zhao et al., 2011, Shiozaki et al., 1993, Yan et al., 2001, Smrcka et al., 2005, Sinz et al., 1998, Aibiki et al., 2000, Jiang et al., 2006, Lee et

al., 2010, Idris et al., 2014, Clifton et al., 2001). Although some lower-quality studies suggest efficacy, the three higher-quality studies show a lack of efficacy (Harris et al., 2009, Andrews et al., 2015, Clifton et al., 2011). There is no evidence of efficacy for prophylactic treatment.

Induced hypothermia is not invasive, has multiple adverse effects, is moderate cost, and has quality evidence of a lack of utility in treatment of TBI. Thus, it is not recommended for treatment of TBI. This may be a treatment option for management of intracranial pressure when other treatments with documented efficacy have failed.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Induced hypothermia; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 276 articles in PubMed, 100 in CINAHL, 26 in Cochrane Library, 18,800 in Google Scholar, and 0 from other sources†. We considered for inclusion 15 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 5 from Google Scholar, and 0 from other sources. Of the 20 articles considered for inclusion, 10 randomized trials and 10 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

LASER THERAPY

Laser therapy or low-level laser therapy has been used for treating pain, inflammation, neurological disorders, and promoting healing of tissues [724-730]. LLLT uses red and NIR light rather than hotter light that is used for cutting and heating tissue. LLLT has been raising interest for treating traumatic brain injury because of purported abilities to inhibit apoptosis, stimulate growth, and increase neurogenesis [725]. See Cervical and Thoracic Spine Disorders Guideline for indications for treatment of the cervical spine.

LOW-LEVEL LASER THERAPY FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of laser therapy in the treatment of patients with TBI. See also the ACOEM Cervical and Thoracic Spine Disorders Guideline.

Strength of evidence No Recommendation, Insufficient Evidence (I)

Level of confidence Low

Rationale

There are no quality studies assessing low-level laser therapy for treatment of TBI. One low-quality trial with potential randomization failure was performed primarily to assess feasibility (Figueiro Longo et al., 2020), and a secondary analysis was suggested as having the potential to improve resting state connectivity (Chan et al., 2024). Low-level laser therapy is not invasive, has negligible adverse effects, is high cost, but has no evidence of treatment efficacy for TBI. Thus, there is no recommendation. See also the ACOEM Cervical and Thoracic Spine Disorders Guideline.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Laser Therapy OR Low-Level Light Therapy OR LLLT; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 118 articles in PubMed, 3 in CINAHL, 9 in Cochrane Library, 18,000 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 2 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MANIPULATION AND MOBILIZATION

For recommendations on manipulation and mobilization, see the ACOEM Cervical and Thoracic Spine guideline.

REGULAR OR ROUTINE MANIPULATION OR MOBILIZATION FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Regular or routine manipulation or mobilization for traumatic brain injury (TBI) is not recommended. See the ACOEM Cervical and Thoracic Spine Disorders guideline for other indications.

Strength of evidence Not Recommended, Insufficient Evidence (I)
Level of confidence High

Rationale

Routine manipulation or mobilization has been studied for the treatment of traumatic brain injury (Riberholt et al., 2020, Thomas et al., 2023). There is no quality evidence of efficacy for prolonged treatment (manipulation several times a month for years). There is no quality evidence that prophylactic treatment is effective for primary prevention (before first episode of pain) or for secondary prevention (after recovery from an episode of cervicothoracic pain), and prophylactic treatment is not recommended. There is also no evidence that manipulation on a regular or routine basis is beneficial.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Manipulation, Osteopathic OR Routine manipulation OR Mobilization; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 148 articles in PubMed, 8 in CINAHL, 103 in Cochrane Library, 18,300 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 4 randomized trials and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

TRANSCRANIAL STIMULATION

TBI often leads to cognitive and emotional impairments such as attention deficit and memory loss. Transcranial direct current stimulation (tDCS) is a noninvasive neuro-modulatory modality that is increasingly being used to improve cognitive function [350, 731, 732]. tDCS involves the application of a weak DC electric current to the scalp to modulate the neurons in the brain [732, 733]. tDCS applied on the motor cortex has been reported to increase the pain threshold and provide relief from neuropathic pain [733].

Transcranial magnetic stimulation uses an electromagnetic coil that is placed against a patient's forehead. It attempts to stimulate or inhibit nerve cells in the brain. TMS has a few different methods of procedure and has been used to treat depression [734]. There have been attempts to use TMS for neurological conditions including TBI [735, 736, 737, 738, 739, 740].

TRANSCRANIAL MAGNETIC STIMULATION (TMS) FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Transcranial magnetic stimulation is not recommended for the treatment of TBI. However, there are other indications for TMS such as migraines and depression (See Depressive Disorders Guideline).

Strength of evidence Not Recommended, Evidence (C)
Level of confidence Low

Rationale

Transcranial magnetic stimulation (TMS) has been studied for the treatment of traumatic brain injury in mild to severe patients (Ahorsu et al., 2021, Hara et al., 2021, Li et al., 2023, Galimberti et al., 2024, Hu et al., 2024). A moderate-quality trial found lack of efficacy of transcranial magnetic stimulation (TMS) for improving executive function (Neville et al., 2019), nor were anxiety symptoms improved in a post-hoc analysis (Rodrigues et al., 2020). The next highest quality study found non-significant trends in improvement (Verisezan Rosu et al., 2023), and another reported a lack of efficacy for neuropsychological function (Franke et al., 2022). Another trial was largely negative (Rao et al., 2019), although there is one study suggesting efficacy (Shen et al., 2023).

There are many low-quality and studies of small sample sizes assessing TMS for treatment of TBI (Vaninetti et al., 2021, Stilling et al., 2020, Siddiqi et al., 2019, Siddiqi et al., 2023, Choi et al., 2018, Hoy et al., 2019, Lee et al., 2018, Moussavi, 2019, Leung et al., 2016). There are numerous systematic reviews, most of which concluded there was no or limited evidence of efficacy for TBI (Hara et al., 2021, Li et al., 2023, Galimberti et al., 2024).

Transcranial magnetic stimulation is not invasive, has no adverse effects, and is high cost. Most studies (including all of the highest-quality studies) suggest lack of efficacy, and thus it is not recommended. There are other indications, including headache and depression (see the ACOEM Depressive Disorders Guideline).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Transcranial Magnetic Stimulation; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 67 articles in PubMed using Most Recent tab, and we did a secondary search in PubMed using Best Match tab to find and review 67 articles, 33 in CINAHL, 15 in Cochrane Library, 16800 in Google Scholar, and 0 from other sources†. We considered for inclusion 12 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 5 from Google Scholar, and 0

from other sources. Of the 17 articles considered for inclusion, 11 diagnostic study and 6 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

TRANSCRANIAL DIRECT CURRENT STIMULATION (TCDS) FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of transcranial direct current stimulation in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Transcranial direct current stimulation (TDCS) has been studied for the treatment of mostly moderate to severe traumatic brain injury patients (Zaninotto et al., 2019). One RCT from Iran reported evidence of efficacy for 6 weeks after treatment (Bakhshayesh Eghbali et al., 2023), and another two trials suggested some efficacy (Kumar, 2022, Quinn et al., 2022). However, one trial reported lack of clinical improvements (Sun, 2023), while another trial reported a lack of efficacy (Lesniak, 2014). There are a few mechanistic studies suggesting potential utility, but they lack meaningful clinical follow-up and outcomes (Ulam et al., 2015, Yoon et al., 2014).

There are additional low-quality studies with small sample sizes assessing TDCS for treatment of TBI (Sacco et al., 2016, Wilke et al., 2017, Quinn et al., 2020, Estraneo et al., 2017). One systematic review included multiple low quality trials and concluded there was "promising preliminary results for post-concussive depression and headache" while there was no conclusion of efficacy for other symptoms (Mollica et al., 2021).

Transcranial direct current stimulation is not invasive, has no adverse effects, and is high cost. With conflicting evidence of efficacy, there is no recommendation for treatment of TBI. However, regarding treatment of depression, please see the ACOEM Depressive Disorders Guideline.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: TREATMENT

TOPIC; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 44 articles in PubMed, 2 in CINAHL, 7 in Cochrane Library, 27,800 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 7 from other sources. Of the 12 articles considered for inclusion, 10 randomized trials and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

DEVICES

MENIETT DEVICE FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against use of the Meniett device for the treatment of select patients with TBI and Meniere disease. However, the panel vote was split (57% of panel members supported No Recommendation (I) and 43% supported Recommended (I)).

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Indications

Unilateral Meniere disease with disruptive levels of vertigo, low frequency sensorineural hearing loss on audiometry, functional level of 2-4 (American Academy of Otolaryngology-Head and Neck Foundation, 1995), abnormal cochleogram in the affected ear (SP/AP click ratio >0.39 or toneburst SP of ≥2.0µV) (Gates et al., 2004).

Benefits

Improved control of vertiginous symptoms, although differences at 4 months compared with sham were relatively modest (Gates et al., 2004).

Harms

Intolerance of device, lack of sufficient control of symptoms, ear infection.

Indications for discontinuation

Sufficient recovery to not need device, intolerance, non-use of device.

Rationale

A sham-controlled trial found the Meniett device effective, although by 4 months there were relatively modest differences compared with sham (Gates et al., 2004, Gates et al., 2006). There are no quality studies assessing Meniett devices for treatment of TBI. A Meniett device is invasive, has some adverse effects, is high cost, has some evidence of efficacy in patients with Meniere disease. However, the panel vote was split with 57% in support of no recommendation and 43% in support of a favorable recommendation (I).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Meniett Device; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 64 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ANKLE-FOOT ORTHOTICS FOR TREATMENT OF FOOT DROP FROM TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Ankle-foot orthotics are selectively recommended for treatment of foot drop associated with TBI injuries.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Benefits

Better able to use the extremity. May help maintain, or reduce losses of, extremity strength through greater use of the extremity.

Harms

Negligible.

Rationale

There are no quality studies assessing adaptive devices for the treatment of TBI. See the ACOEM Ankle and Foot Disorders Guideline regarding foot drop. Adaptive devices, casts, and orthotics are not invasive, have minimal adverse effects, are moderate cost, have been found to be helpful for treatment including ambulation, and thus are recommended for select treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: ankle-foot orthotics, foot orthoses, orthotics; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 0 in CINAHL, 3 in Cochrane Library, 4010 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

INJECTION THERAPY

BOTULINUM TOXIN

Botulinum toxin has been used for treatment of spasticity related to TBI [579, 581, 582, 586, 587, 741, 742]. It is also used for cervical spine-related conditions.

BOTULINUM INJECTIONS FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Botulinum toxin is recommended for use in the treatment of spasticity related to TBI. Indications for cervical spine related conditions are in the Cervical and Thoracic Spine Guideline.

Strength of evidence Recommended, Evidence (C)

Level of confidence Low

Indications

Spasticity related to TBI. Also is used for treatment of chronic migraine.

Benefits

Reduction in spasticity.

Harms

Muscle weakness. May result in death if overdosed.

Frequency/Dose/Duration

The highest-quality placebo-controlled trial used Botulinum 100U in 5mL/2mL NS injection (above/below elbow diluent). 50U injected into each of FCR and FCU. Other muscles from shoulder to hand injected up to 500U (Simpson et al., 2009).

Indications for discontinuation

Sufficient resolution of spasticity, adverse effects.

Rationale

Both high- and moderate quality placebo-controlled trials suggested botulinum is superior for management of spasticity (Simpson et al., 2009, Verplancke et al., 2005, Gracies et al., 2015), and one of the trials found comparable results to physiotherapy (Verplancke et al., 2005). Benefit durations of 18-22 weeks were reported in the higher quality trial (Simpson et al., 2009).

Botulinum toxin is invasive, has significant adverse effects (especially if overdosed), is high cost, but has evidence of treatment efficacy. Thus, it is recommended for treatment of spasticity related to TBI. See the ACOEM Cervical and Thoracic Spine Disorders Guideline for cervical spine-related indications.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Botulinum Toxins; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 67 articles in

PubMed, 5 in CINAHL, 14 in Cochrane Library, 11,900 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 3 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

NERVE BLOCKS

Diagnostic and therapeutic nerve blocks involve a percutaneous needle filled with lidocaine or another local anesthetic and are used to target specific nerves. Most commonly in patients with TBI, these are to target one or both of the occipital nerve branches. Nerve blocks trialed also include supraorbital, supratrochlear and auriculotemporal. These are used to attempt to determine and evaluate headaches, spasticity, ROM and/or dystonia. Generally, these blocks are performed simultaneously for both diagnostic and therapeutic purposes. There also are nerve blocks commonly administered for cervical nerve roots to address neck-related pain. Occipital nerve blocks have been used to treat migraine and cervicogenic headaches [(743-746)]. Greater occipital nerve blockade has been used to treat episodic cluster headache [(747)] and for migraines [(748)].

See also the ACOEM Cervical and Thoracic Spine Disorders guideline for recommendations on radiofrequency neurotomy/ablation.

OCCIPITAL NERVE BLOCKS FOR CERVICOGENIC HEADACHE

Recommended

Occipital, auriculotemporal, sphenopalatine, lesser occipital, supraorbital, and supratrochlear nerve blocks are recommended for the treatment of cervicogenic headache.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Unilateral cervicogenic headaches, with headache precipitated by neck movement or pressure over the greater occipital nerve, reduced neck range of motion (Naja et al., 2006). Posttraumatic migraine headaches are another potential indication. Whiplash injury was excluded from the Naja study. Headaches should be resistant to other forms of treatment (e.g., NSAID, acetaminophen, stress reduction, exercise etc.).

Benefits

Potential for reduced headache intensity, frequency and duration. Potential for reductions in use of other medications.

Harms

Medicalization of the case, especially as average pain relief of 3.67 days vs. 1.52 days for normal saline (Naja et al., 2006). Rare procedure complications.

Frequency/Dose/Duration

The highest-quality study showing limited short-term efficacy for cervicogenic headaches used 10mL (3 mL 2% lidocaine, 3 mL 2% lidocaine with epinephrine 1:200,000, 2.5 mL 0.5% bupivacaine, 0.5 mL fentanyl 50 µg/mL, and 1mL clonidine 150 µg/mL).

Rationale

There are two high-quality trials with conflicting results, one suggesting efficacy for cervicogenic headache (Naja et al., 2006) and one suggesting a lack of efficacy for migraines (Dilli et al., 2015), resulting in questions regarding whether efficacy may differ based on the diagnosis. Two moderate quality trials suggested efficacy for migraines (Cuadrado et al., 2016, Inan et al., 2015). Thus, the overall quantity of quality literature is small and conflicts for migraine headaches. There is no long-term study showing efficacy for treatment of cervicogenic headaches, and there is one trial without placebo control suggesting comparable efficacy with a transcutaneous stimulation device (Gabrhelik et al., 2011).

Occipital, auriculotemporal, sphenopalatine, lesser occipital, supraorbital, and supratrochlear nerve blocks are invasive, have some adverse effects, are moderate to high cost over time, and have some evidence of short-term efficacy. Thus, they are recommended for treatment of cervicogenic and migraine headaches thought to be related to the TBI event that are resistant to other forms of treatment.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: occipital nerve block; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 4,270 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are

reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

OCCIPITAL AND SUPRAORBITAL NERVE STIMULATION

Occipital nerve stimulation has been attempted both transcutaneously (noninvasive) [749] and by implanted stimulator [750-752].

NONINVASIVE OCCIPITAL AND SUPRAORBITAL NERVE STIMULATION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Noninvasive occipital and supraorbital nerve stimulation is recommended for the treatment of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Non-allodynia pain (i.e., not overly sensitive to pain on palpation of neck/scalp or other stimulation; may be assessed with 12-item allodynia symptoms checklist, ASC-12 (Lipton et al., 2010)). Chronic migraine or tension headaches (Bono et al., 2015) thought to be related to the TBI event. Headaches should be resistant to other forms of treatment (e.g., NSAID, acetaminophen, stress reduction, exercise etc.) (Serra et al., 2012). At least 2 months of medication withdrawal for medication overuse headaches (Serra et al., 2012).

Benefits

Potential for reduced headache intensity, frequency and duration. Potential for reductions in use of other medications.

Harms

Medicalization of the case.

Frequency/Dose/Duration

Sessions of 30 min/day for 2 weeks.

Rationale

A few moderate-quality RCTs found headache reductions compared with sham (Bono et al., 2015). One trial found the reductions lasted beyond the 2 weeks of treatment to the

duration of the trial of 60 days with 86% vs. 4% of nonallodynic patients achieving at least 50% reduction in headache days (Bono et al., 2015).

Cutaneous nerve stimulation administered in sessions is not invasive, has minimal adverse effects, is high cost, and has some evidence of short- to intermediate-term efficacy. Thus, it is selectively recommended for treatment of cervicogenic and migraine headaches thought to be related to the TBI event that are resistant to other forms of treatment.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Non-invasive occipital nerve stimulation; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 11,800 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

IMPLANTABLE OCCIPITAL NERVE STIMULATION (ONS) DEVICES FOR TRAUMATIC BRAIN INJURY (TBI)

Not Recommended

Implantable occipital nerve stimulation (ONS) devices are not recommended for use in the treatment of patients with TBI.

Strength of evidence Not Recommended, Insufficient Evidence (I)
Level of confidence Low

Rationale

There is one moderate-quality trial of patients with chronic migraines suggesting lack of efficacy (Silberstein et al., 2012). There is one report of some efficacy in a longer-term, but open-label trial for treatment of migraine headaches (Dodick et al., 2014). The same trial reported high rates of adverse events with 20/177 (11.3%) having unsuccessful trials, 9/105 (8.6%) having explantation in the active device group in the first year, and an overall

experience of adverse events affecting 70.7% of the patients. Low-quality evidence has suggested potential efficacy (Reed KL, 2015).

Implantable devices are invasive, have significant adverse effects, and are high cost. With the only quality trial suggesting lack of efficacy, there is a need for further quality trials to establish efficacy. Additionally, the only quality trial of size was for migraine headaches, which is of questionable use for treatment of patients with TBI. These devices may be a consideration for limited use in patients with normal psychological profiles, no evidence of malingering, and headaches refractory to numerous treatments and preventives, including, but not limited to, multiple classes of pharmaceuticals and botulinum.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Implantable occipital nerve stimulation devices; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 17,500 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BEHAVIORAL AND PSYCHOLOGICAL INTERVENTIONS

Traumatic brain injuries lead to neurobehavioral impairments such as physical, psychologic, and behavioral challenges [(753)]. For survivors of serious brain injury, behavioral symptoms, including marked irritability, aggression, and various forms of regressed social functioning, commonly increase over time as other indicators of functional disability decrease [(753-760)].

BEHAVIORAL PROGRAMS FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Behavioral programs are recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Moderate to severe TBI with behavioral issues, especially if not trending towards resolution.

Benefits

Improved awareness and function. Resolution of functional and impairing difficulties, especially those that may inhibit return to quality life and work.

Harms

Medicalization.

Frequency/Dose/Duration

The highest quality study included social skills training program of 12 weekly 3-hour group sessions with therapist plus 1 weekly individual session with clinical psychologist (McDonald et al., 2008), while another study used web-based approaches (McLaughlin et al., 2013).

Indications for discontinuation

Resolution of symptoms, sufficient recovery to function, lack of compliance, reaching a clinical plateau.

Rationale

Behavioral programs have been studied for the treatment of mild to severe traumatic brain injury (Minen et al., 2019, Wheeler et al., 2022, Chuaykarn et al., 2024). There are no quality sham-controlled trials. One trial suggested comparable efficacy between cognitive behavioral therapy (CBT) and supportive psychotherapy (Ashman et al., 2014). Another trial found that graded exposure therapy was superior to endurance coping for helping to reduce avoidance behavior while increasing endurance behavior (Silverberg et al., 2022). Data suggest equal lack of efficacy of the curriculum-based advocacy training compared with usual care (Brown et al., 2015). There is quality evidence of efficacy of CBT which is reviewed elsewhere. The overall literature base has much heterogeneity in methods and interventions which preclude an evidence-based treatment recommendation (Minen et al., 2019). Yet, these programs have some empirical evidence of efficacy.

Behavioral programs are not invasive, have negligible adverse effects, are moderate cost, have no quality evidence of treatment efficacy, but are thought to be effective and necessary for recovery from some sequalae. Thus, they are recommended for treatment of TBI, although the heterogeneity of the literature precludes a letter-grade evidence rating.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Behavioral

programs; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 480 articles in PubMed, 4 in CINAHL, 12 in Cochrane Library, 18000 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 2 from other sources. Of the 6 articles considered for inclusion, 4 randomized trials and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COGNITIVE BEHAVIORAL THERAPIES

Cognitive therapies have been used to rehabilitate patients with traumatic brain injuries [210, 761].

COGNITIVE BEHAVIORAL THERAPY FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Cognitive behavioral therapy (CBT) is recommended for use in the treatment of patients with accompanying anxiety and/or depression, PTSD, postconcussive symptoms, headaches, and hopelessness. CBT is also thought to be particularly helpful among those with mild TBI/concussion and comorbid mood changes.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

TBI patients with accompanying anxiety and/or depression, PTSD, post-concussive symptoms, headaches, and hopelessness.

Benefits

Improved management of cognitive function and psychosocial factors.

Harms

Negligible.

Frequency/Dose/Duration

Frequency is generally tailored based on individual factors of severity and need.

Indications for discontinuation

Resolution, completion of a treatment course, noncompliance.

Rationale

Cognitive behavioral therapy (CBT) has been studied for the treatment of mild to severe traumatic brain injury patients (Chen et al., 2020, Little et al., 2021, Ludwig et al., 2020, Li et al., 2021, Barua et al., 2024). There are many quality studies assessing cognitive behavioral therapies for treatment of TBI, most of which suggest some efficacy for treatment of associated depression and/or depression (Ashman et al., 2014, Potter et al., 2016, Fann et al., 2015, Erickson et al., 2024, Ponsford et al., 2016, Brenner et al., 2018, Ponsford et al., 2020), PTSD (McGeary et al., 2022), postconcussive symptoms/quality of life (Potter et al., 2016, Exner et al., 2022, Cooper et al., 2017, Vanderploeg et al., 2018, Scheenen, 2017), and hopelessness (Brenner et al., 2018); comparable efficacy with supportive psychotherapy (Ashman et al., 2014), but both efficacy (McGeary et al., 2022) and inefficacy for postconcussive headaches (Kjeldgaard et al., 2014). Mindfulness-based cognitive therapy has also been reportedly effective for depression (Bedard et al., 2014).

The VA's CogSMART program of psychoeducation, habit learning, and compensatory strategies was reportedly effective for postconcussive symptoms, cognitive performance, and quality of life (Twamley et al., 2015). A brief phone intervention was found to be effective compared with CBT for early follow-up of at-risk patients with mild TBI (Scheenen, 2017). A trial reported superiority of an in-hospital cognitive rehabilitation program to a limited home rehabilitation program for RTW at 1 year (Salazar et al., 2000). There are many low-quality studies (Tomfohr-Madsen et al., 2020, Silverberg et al., 2013, Rioux et al., 2024, Malarkey et al., 2024, Hsieh et al., 2012, Bryant et al., 2003). Systematic reviews with/out meta-analyses conclude there is evidence of efficacy of CBT for depression and anxiety symptoms related to TBI (Barua et al., 2024, Little et al., 2021), and evidence of efficacy for sleep quality and pain (Li et al., 2021), although not for treatment of severe TBI symptoms (Chen et al., 2020) and not for internal anger.

Cognitive behavioral therapy is not invasive, has no adverse effects, is low cost, and has evidence of efficacy for treatment of TBI accompanied by anxiety and/or depression, PTSD, postconcussive symptoms, headaches, and hopelessness. Therefore, it is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Cognitive Behavioral Therapy OR CBT; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized

controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 216 articles in PubMed, 40 in CINAHL, 72 in Cochrane Library, 19,500 in Google Scholar, and 0 from other sources†. We considered for inclusion 24 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 26 articles considered for inclusion, 20 randomized trials and 6 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMMUNITY-BASED LIFE GOALS

Acquired brain injury is a significant health problem, which often has considerable consequences for societal participation of those affected. Those with severe psychosocial problems may experience difficulties with community reintegration [762]. Community-based rehabilitation programs for people with a brain injury are diverse [763]. The results of the perspective study indicate that the improvements of independent living and societal participation are not achieved at the expense of emotional stability [762].

COMMUNITY-BASED LIFE GOALS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of community-based life goals in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies with sufficient data reporting to support an evidence-based recommendation (Ownsworth et al., 2008, Løvstad et al., 2024). Community-based life goals are not invasive, have negligible adverse effects, but in the absence of quality evidence, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Community goals, Community-based goals, Community-based life goals; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials,

randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 134 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 randomized trial and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

EMOTIONAL TRAINING AND ANGER MANAGEMENT

Emotional training interviewing has been used for treatment of patients with TBI [764]. Anger sometimes occurs either to have caused the TBI, or as a consequence of it. Anger management therapy has been used to treat anger issues in patients with TBI [765]. As with many cases of traumatic brain injuries (TBI), the recovery and treatment phase to improve the lifestyle of the patient. One particular area that patients are overcoming is anger management. It was observed that more family support and participation help patients deal with anger management [766]. Patients with anger after undergoing TBI is a complex, multifaceted problem that should be underestimated and should be observed as psychological adjustment in difficulty [767].

EMOTIONAL TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Emotional training is recommended for use in the treatment of select patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients with emotional problems after TBI, able to comprehend short paragraphs, and scores at least one standard deviation below the mean on a test of facial affect recognition (Radice-Neumann et al., 2009). The sole quality study included only those more than one year after TBI, however earlier treatment may be selectively appropriate. Patients with mild TBI are not expected to need emotional training due to the TBI (Panayiotou et al., 2010), although emotional training may be needed for pre-existing reasons.

Benefits

Potential to improve emotional interpretations and including understanding/reading facial expressions.

Harms

Negligible.

Frequency/Dose/Duration

Regimens varied: regimens ranged from 9 hours over 2-3 weeks (Neumann et al., 2015), 1-hour sessions per week for 16-20 weeks (Westerhof-Evers et al., 2017), 1-hour sessions, 3 times per week for 2-3 weeks (Radice-Neumann et al., 2009), and 8 two-hour sessions given over 4 days (Tornas et al., 2016).

Rationale

Emotional training has been studied for the treatment of traumatic brain injury among patients with mostly moderate to severe TBI (Wheeler et al., 2022). Multiple moderate-quality trials (Tornas et al., 2016, Tornås et al., 2016, Westerhof-Evers et al., 2017, Radice-Neumann et al., 2009) evaluate the usage of emotional training in patients with TBI. These studies suggested emotional training was successful in improving facial recognition and emotional processing (Tornas et al., 2016, Tornås et al., 2016, Westerhof-Evers et al., 2017, Radice-Neumann et al., 2009); however, one study contained baseline differences in time from injury (Tornås et al., 2016). There are additional low-quality studies (Whiting, 2020). Emotional training is not invasive, has negligible adverse effects, is moderate cost in aggregate, has some potential evidence of effectiveness, and thus is recommended for selective treatment of patients with severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: emotional training**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 155 articles in PubMed, 0 in CINAHL, 10 in Cochrane Library, 21,200 in Google Scholar, and 1 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Of the 6 articles considered for inclusion, 5 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles,

we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ANGER MANAGEMENT THERAPY FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Anger management therapy is recommended for treatment of select patients with TBI having anger management issues. Anger problems often accompany orbitofrontal syndromes and anger management is frequently conducted in concordance with neuropsychiatry and medication(s).

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients with TBI with anger management needs, either as an underlying cause of the TBI or as a consequence of it.

Benefits

Better anger management.

Harms

Negligible.

Frequency/Dose/Duration

One low quality trial utilized 5 to 8 weekly individual therapy sessions (Medd, 2000).

Rationale

Anger management has been studied for the treatment of traumatic brain injury with trials involving patients of somewhat unclear severity (Verberne et al., 2019, MacKenzie et al., 2024). There is one quality study comparing two groups of eight sessions of anger self-management training compared with eight sessions of personal readjustment and education training that suggested modest efficacy of ASMT for anger (Hart et al., 2017). There are some low-quality studies (Neumann et al., 2023, Medd, 2000, Aboulafia-Brakha et al., 2016). One systematic review found overall relatively poor quality of psychological interventions for neuropsychiatric consequences of TBI (Verberne et al., 2019), while another concluded there was evidence of efficacy for anger self-management programs (MacKenzie et al., 2024). Anger management therapy is not invasive, has negligible adverse effects, is moderate cost in aggregate, has some evidence of efficacy, and thus is recommended for selective treatment of patients with TBI with anger issues.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Anger management**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 22,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 4 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

GOAL SETTING

Goal setting has been included in the treatment of patients with TBI [768-772].

GOAL SETTING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Goal setting is recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients with chronic TBI symptoms.

Benefits

Improved cognitive function including attention/executive function and functional task performance.

Harms

Negligible.

Frequency/Dose/Duration

One of the quality trials used a regimen of 8-sessions over 4 months (Borgen et al., 2023).

Indications for discontinuation

Completion of a course, resolution or non-compliance.

Rationale

Goal setting has been studied for the treatment of traumatic brain injury with severity reportedly mostly moderate to severe and mostly chronic (Prescott et al., 2015, Plant et al., 2016, Knutti et al., 2022). Most quality studies suggest efficacy (Hassett et al., 2015, Doig et al., 2009, Fischer et al., 2004, Novakovic-Agopian et al., 2018). One trial was negative for the primary outcome but suggested reduced anxiety (Borgen et al., 2023). Two moderate-quality trials both have small sample sizes, underpowering and poor reporting of results (McPherson et al., 2009, Ownsworth et al., 2008). Systematic reviews conclude there is evidence of efficacy (Knutti et al., 2022). These approaches to goal setting are not invasive, have no adverse effects, are moderate cost in aggregate, and have evidence of efficacy; therefore, they are recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: goal setting**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 98 articles in PubMed, 3 in CINAHL, 14 in Cochrane Library, 19,400 in Google Scholar, and 0 from other sources†. We considered for inclusion 5 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 2 randomized trials and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MOTIVATIONAL INTERVIEWING

Motivational interviewing has been used for treatment of patients with TBI [(773)].

MOTIVATIONAL INTERVIEWING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Motivational interviewing is recommended for use in the treatment of patients with anxiety or depressive symptoms after TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients with anxiety or depressive symptoms after TBI.

Benefits

Potential to improve depressive and anxiety symptoms after TBI.

Harms

Negligible.

Frequency/Dose/Duration

Regimens varied. They have included four 20-minute sessions (Zatzick et al., 2014), 10 weekly 2-hour sessions (Simpson et al., 2011), to one session at 1, 2, 3, 5, 7, and 9 months after initial treatment (Bombardier et al., 2009, Bell et al., 2005).

Indications for discontinuation

Completion of a course of training, resolution, or noncompliance.

Rationale

Motivational interviewing has been studied for the treatment of patients with mild to severe traumatic brain injuries (Mueller et al., 2018, Flores-Sandoval et al., 2024). Multiple moderate-quality trials suggest that motivational interviewing is successful at reducing symptoms of anxiety and depression for patients with TBI (Ponsford et al., 2016, Hsieh et al., 2012, Bombardier et al., 2009), with two utilizing cognitive behavioral therapy (Ponsford et al., 2016, Hsieh et al., 2012). However, one trial had baseline differences in groups concerning for potential randomization failure (Ponsford et al., 2016). One moderate-quality study suggested motivation interviewing can improve overall function (Bell et al., 2005). Three moderate-quality studies evaluated the usage of motivation interviewing for the treatment of alcohol consumption problems (Zatzick et al., 2014, Tweedly et al., 2012, Ponsford et al., 2012). Two studies suggest efficacy (Zatzick et al., 2014, Tweedly et al., 2012) but one suggests readiness to change influences the effectiveness of treatment (Ponsford et al., 2012). Motivational interviewing with cognitive behavioral therapy is not invasive, has negligible adverse effects, is moderate cost in aggregate, has some potential evidence of effectiveness, and therefore is recommended for selective treatment of patients with anxiety or depressive symptoms and/or alcohol consumption problems after TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: motivational interviewing**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 4 articles in PubMed, 0 in CINAHL, 1 in Cochrane Library, 21,700 in Google Scholar, and 2 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 1 from Cochrane Library, 2 from Google Scholar, and 2 from other sources. Of the 5 articles considered for inclusion, 2 randomized trials and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

PEER MENTORING PROGRAM

A social peer mentoring program has been included in the treatment of patients with TBI [774] to address social isolation that has been reported in this population [775-778].

PEER MENTORING PROGRAM FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of a peer mentoring program in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality trials and one low-quality study of a peer mentoring program (Struchen et al., 2011). Peer mentoring is not invasive, has no adverse effects, and is moderate to high cost in aggregate. In the absence of quality evidence of efficacy, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Peer Monitoring;

traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 20,000 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

PERCEPTUAL SKILLS

Perceptual deficits are common in adults with diffuse brain injury [779]. Perceptual training involves using tasks like construction of puzzles to improve functional performance [779]. Perceptual training can take place on the computer [780] or completing other functional tasks such as puzzles [779]. Perceptual training includes basic visual scanning, somatosensory awareness and size estimation training, and complex visual perceptual organization [781].

In cognitive rehabilitation, verbal labeling training is used to provide feedback to patients with TBI through tasks to improve performance [782]. The use of verbal and visual feedback improves self-awareness to patients with TBI during occupational performances [782]. Interpersonal Process Recall (IPR) is a technique that specifically uses “videotaped interactions of participants with a professional in order to facilitate therapy” [783]. IPR is used specifically to help researchers “gain access to participants’ silent in-session experiences as remembered by the participant” [784]. These silent experiences may include “feelings, emotions, body language, and subconscious reasoning" [785]. Participants are “recorded interacting with a counselor and then are exposed to that recording with the counselor present” [783]. There is a “remote control present in case the participant or the counselor wishes to pause the recording at specific moments” [783]. IPR strives to “accelerate participants’ recovery process with counseling by identifying underlying reasoning for specific actions during the interaction” [785].

PERCEPTUAL SKILLS TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for perceptual skills training for patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies specifically addressing perceptual skills training, and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Perceptual Skills Training; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 134 articles in PubMed, 15 in CINAHL, 11 in Cochrane Library, 19100 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VERBAL LABELING TRAINING AND COMPENSATORY INTERPERSONAL PROCESS RECALL FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Verbal labeling training and compensatory interpersonal process recall is selectively recommended for patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients with moderate to severe chronic and postoperative TBI with impaired self-awareness, who are at least 1 year post-TBI.

Benefits

Improved self-awareness.

Harms

Negligible.

Frequency/Dose/Duration

Preparation of 4 meals with 2-4 days between each meal.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

There is one moderate-quality study (Schmidt et al., 2012) showing combination video plus virtual feedback was effective in patients with TBI as measured by the number of errors made in meal preparation. This intervention is not invasive, has negligible adverse effects, is moderate cost, and is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Verbal labeling training OR Interpersonal process recall OR IRP; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 5 articles in PubMed, 0 in CINAHL, 5 in Cochrane Library, 17,600 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

PROBLEM SOLVING

Compensatory (or adaptive) approaches have been used for the rehabilitation of cognitive deficits to improve memory performance [786-788]. Remediation or restorative interventions aim to improve the specific underlying cognitive deficit through cognitive exercises such as drills, worksheets, or computer-based programs [789]. CACR uses a computer platform to administer cognitive exercises that target cognitive processes such as visual perception, visual attention, working memory, and remembering written directions and visual patterns [790-792].

GROUP SESSIONS FOR PROBLEM-SOLVING FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Group sessions for problem-solving, discussion of social isolation, and discussion of frustrations are selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients who are at least 1 year post-TBI with documented impairments in social/vocational functions, but with cognitive functional abilities that include: taking organized notes, giving and receiving feedback, relating to others with adequate social skills, and sustaining attention for an hour-long session (Rath, 2003).

Benefits

Improved communication, coping skills, and problem-solving.

Harms

Negligible.

Frequency/Dose/Duration

Weekly for 12 weeks (Dahlberg et al., 2007) to 24 weeks (Rath, 2003).

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

Group sessions for problem solving, discussion of social isolation, and discussion of frustration have been studied for the treatment of traumatic brain injury (Patterson et al., 2016). There are two moderate-quality studies involving group sessions for patients with chronic TBI in comparison with either no or conventional treatment (Dahlberg et al., 2007) (Rath, 2003). Both studies showed patients improved at 6 months and 1 year. Another trial suggested no differences between interactive vs. noninteractive treatment groups (Harrison-Felix et al., 2018). Group therapy is noninvasive, has negligible adverse effects, and is moderate to high cost depending on duration. Thus, it is recommended for patients with cognitive deficits.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Group sessions OR Problem Solving OR Social Isolation OR frustrations OR Psychotherapy, Group; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 357 articles in PubMed, 29 in CINAHL, 39 in Cochrane Library, 18,800 in Google Scholar, and 0 from other sources†. We considered for inclusion 9 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 9 articles considered for inclusion, 8 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMPENSATORY SKILLS TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Compensatory skills training is recommended for the treatment of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients with moderate-severe TBI that includes difficult problem solving and executive dysfunction.

Benefits

Improved problem solving, executive function, anxiety, self concept, and interpersonal communication.

Harms

Negligible.

Frequency/Dose/Duration

STEP program is 9 hours per week for 12 weeks.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

Compensatory skills training has been studied for the treatment of traumatic brain injury among patients studies with mild to severe TBI (Alashram, 2024). Multiple moderate-quality trials suggest efficacy of compensatory skills training (Cantor et al., 2014, Fleming, 2024, Fleming et al., 2022, Storzbach et al., 2017, Pagulayan et al., 2017, O'Neil et al., 2021). There is one moderate-quality study involving compensatory skills training (Cantor et al., 2014) suggesting STEP is efficacious in self-reported TBI problem solving and executive function. One trial suggested the modified Story Memory Technique was effective (Chiaravalloti et al., 2015). One trial found efficacy for one of the measures as there was evidence of improved return to work at 3 months (Howe et al., 2020). Two low-quality studies both have small samples; one study shows comparable efficacy between both groups (Bergquist et al., 2009) and the other study (Helffenstein et al., 1982) reported improved anxiety, self-concept, interpersonal skills, and communication skills compared to control group. This type of intervention is noninvasive, low- to moderate-cost depending upon therapist time and number of sessions, has negligible adverse effects, and thus is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Compensatory skills training; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 8 articles in PubMed, 0 in CINAHL, 22 in Cochrane Library, 18,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 7 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 7 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SUBSTANCE ABUSE COUNSELING

Substance abuse counseling has been used as a preventive action to minimize substance abuse following a traumatic brain injury (TBI) [793, 794].

SUBSTANCE ABUSE COUNSELING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Substance abuse counseling is recommended for use in the treatment of patients with TBI with substance use disorder.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Illicit substance use, substance abuse, substance involved in TBI event, and/or problematic substance use.

Benefits

Potential for reduced risk of future injury, reduced adverse health risks.

Harms

Negligible.

Rationale

There are quality studies and systematic reviews reporting evidence of modest efficacy of counseling programs (Zatzick et al., 2014, Tweedly et al., 2012, Vungkhanching et al., 2007, Amato L, 2005, Jiang S, 2017, Beaulieu M, 2021). Substance abuse counseling is not invasive and has negligible adverse effects. In the absence of quality evidence, it is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Substance abuse counseling; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 18,300 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of

100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SUICIDE PREVENTION

Patients with TBI are susceptible to depression and suicide, thus suicide prevention has been included in some programs [795]. Population-based data document a 3.3-fold risk of suicide [796]. Scheduled telephone interventions have also been used for patients with TBI with depressive symptoms [797]. Neuropsychological impairments such as dysfunction of memory and speed of information processing are post-concussion symptoms that can cause significant psychosocial problems following TBI [797-801].

SUICIDE PREVENTION FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Suicide prevention is selectively recommended for treatment of patients with TBI who have depressive disorders or other risk factors.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients with depressive symptoms, depression, with or without suicidal ideation.

Benefits

Potential to prevent suicides

Harms

Negligible.

Frequency/Dose/Duration

One moderate-quality trial utilized 10 weekly 2-hour sessions among those with severe TBIs (Simpson et al., 2011). A trial also used a scheduled telephone intervention among those who had had inpatient rehabilitation for TBI (Bombardier et al., 2009).

Rationale

One moderate-quality trial suggested psychological treatment was successful in producing improvement in hope that persisted for 3 months among those who had had severe TBI (Simpson et al., 2011). Suicide prevention training is not invasive, has negligible adverse effects, is moderate cost in aggregate, has evidence of effectiveness to reduce hopelessness, and thus is recommended for selective treatment of patients with TBI with depressive symptoms or depression, with or without suicidal ideation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: suicide prevention; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 1 article in PubMed, 1 in CINAHL, 1 in Cochrane Library, 21200 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 1 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

REHABILITATION

ACTION SEQUENCES

(Re)learning a series of actions is essential for function, both in the home and workplace. This has been used for treatment of patients with TBI [802, 803].

ACTION SEQUENCES FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Action sequences are recommended for use in the treatment of patients with severe TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients with severe TBI with requirements to (re)learn sequences of functional tasks.

Benefits

Better learning of required tasks.

Harms

Negligible.

Frequency/Dose/Duration

Modeling the activities to be taught is reportedly superior to molding, with 69% better longer-term recall of a learned sequence (Zlotowitz et al., 2010).

Rationale

There is one moderate-quality RCT (Zlotowitz et al., 2010) and one low quality trial (Bublak et al., 2000). The sole quality study suggests some evidence of efficacy. These principles appear equally applicable to vocational rehabilitation as to activities of daily living, although there is no quality study regarding teaching occupationally relevant action sequences. Teaching action sequences is not invasive, has negligible adverse effects, is low to moderate cost and has some data suggesting some efficacy and so is recommended for treatment of select patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Action sequences; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 11 article in PubMed, 1 in CINAHL, 14 in Cochrane Library, 17,900 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ATTENTION TRAINING

Attention deficits are one of the most frequent cognitive consequences following the TBI [324, 804, 805]. Attention regulation training is designed to help an individual increase the ability to focus on certain tasks or information [324, 806-809]. Computerized attention training (visual, auditory, divided training) has been used to treat patients with TBI [784, 810] shows the relations of the cognitive abilities and psychiatric symptomatology with the level of functioning in the functional domains. Recreational computing including micro-computer delivered attention training has been used to treat patients with TBI [804, 811]. Restorative computer and non-computer attention remediation has been used to treat patients with TBI [812-, 814].

ATTENTION REGULATION TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Attention regulation training is recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients with moderate to severe TBI with indications of impaired attention, as well as problems with dual-tasking (Couillet et al., 2010). Select patients with ongoing symptoms from mild TBI may be candidates.

Benefits

Improvements in sustained attention, focus and cognitive functioning.

Harms

Negligible.

Frequency/Dose/Duration

Trials used various doses, including: 10x2-hr group-based training sessions, 3x1-hr individual training sessions and approximately 20 hrs of home practice over 5 weeks.

Indications for discontinuation

Sufficient recovery, ability to dual task, plateau, non-compliance with home exercises.

Rationale

Attention regulation training has been studied for the treatment of traumatic brain injury for subacute traumatic brain injury (Radomski et al., 2016). There are a few quality studies for the use of attention regulation training to treat patients with TBI, and they mostly suggest efficacy, although the studies are heterogenous and not readily comparable (Couillet et al., 2010, Shum et al., 2011, Novakovic-Agopian et al., 2011, Novakovic-Agopian et al., 2021, Kryza-Lacombe et al., 2023, McMillan et al., 2002, Elbogen et al., 2019). There are multiple low-quality studies (Novakovic-Agopian et al., 2021, Polich et al., 2020, Chen et al., 2011, Niemann et al., 1990).

Attention regulation training is not invasive, has no adverse effects, and is low to moderate cost in aggregate. With most evidence suggesting modest efficacy, it is recommended for treatment of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Attention regulation training OR directed attention**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 77 articles in PubMed, 5 in CINAHL, 33 in Cochrane Library, 18,500 in Google Scholar, and 0 from other sources†. We considered for inclusion 5 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 7 randomized trials and 2 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ATTENTION PROCESS TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Attention process training is recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

For patients with subacute to chronic, moderate and severe TBI. May apply to select patients with mild TBI with these cognitive deficits.

Benefits

Improvement in performance of attention related tasks.

Harms

Negligible.

Frequency/Dose/Duration

10 weeks of APT training (one hour per week) times 3 days for 10 weeks.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

There are no quality studies involving APT. There is one study (Sohlberg et al., 2000) showing improvement in patient self reported attention related tasks and psychological function, although the study had a small sample size. This intervention is not invasive, has few adverse effects, is low cost, and is therefore recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Attention Process Training, ATP; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 60 articles in PubMed, 0 in CINAHL, 9 in Cochrane Library, 17,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 randomized trial and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

RECREATIONAL COMPUTING FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for recreational computing for the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There is one low-quality study (Gray et al., 1992) with a small sample suggesting the experimental group performed better on tests at 6 months (PASAT and WAIS-R). This

intervention has not been shown effective in a quality trial, has not been replicated, over 30 years have passed since the publication of one low-quality trial, and thus there is no recommendation for recreational computing.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Recreation Therapy OR Recreation computing; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 124 articles in PubMed, 0 in CINAHL, 2 in Cochrane Library, 22,400 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMPUTERIZED ATTENTION TRAINING WITH VISUAL, AUDITORY, AND DIVIDED TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Computerized attention training is recommended for use in the treatment of patients with chronic TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

For chronic TBI patients at least 12 months postinjury with attention issues.

Benefits

Improved attention measures.

Harms

Negligible.

Frequency/Dose/Duration

Six 2-hour sessions for 9 weeks.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

Computerized attention training with visual, auditory, and divided training has been studied for the treatment of traumatic brain injury (Bogdanova et al., 2016). There is one moderate-quality study (Niemann et al., 1990), suggesting computerized attention training significantly improved on measures of attention. Two low-quality trials also suggest efficacy (Ruff et al., 1990, Gray et al., 1992). This treatment is not invasive, has low adverse effects, is moderate to high cost, and is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: computerized attention training with visual, auditory, and divided training**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 29 articles in PubMed, 29 in CINAHL, 3 in Cochrane Library, 18,800 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 2 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

"CAPTAIN'S LOG"- COMPUTER TRAINING PROGRAM FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of Captain's Log computer training program for attention skills (with tasks for vigilance, inattention, prudence, impulsivity, focus, variability, and speed) in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)

Level of confidence Low

Rationale

There are no quality studies using the Captain's Log for improved attention in patients with TBI. This intervention is not invasive, has no adverse effects, is low to moderate cost, but there is no recommendation in the absence of quality evidence.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Captain's Log; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 13,100 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

RESTORATIVE COMPUTER AND NON-COMPUTER ATTENTION REMEDIATION

No Recommendation

There is no recommendation for or against the use of restorative computer and noncomputer attention remediation in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies involving restorative computer and noncomputer attention remediation. This technique is not invasive, has low adverse effects, is moderate to high cost, and in the absence of quality evidence, there is no recommendation for or against this treatment.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Restorative computer attention remediation OR attention remediation; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 30 articles in PubMed, 0 in CINAHL, 22 in Cochrane Library, 12,600 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BALANCE TRAINING

Vestibular dysfunction is reportedly common in patients with TBI [215]. Adults with mild traumatic brain injury may acquire some vestibular dysfunction. Vestibular dysfunction is associated with dizziness, vertigo, visual blurring, oscillopsia (a jumping of the visual field associated with movement of the head), and feeling off balance [815]. Vestibular therapy aims to decrease these symptoms and improve dynamic and static balance by utilizing exercises that target these impairments [816]. For the best outcomes, exercises should be individualized to the patient. Often, this means taking extensive amounts of information regarding history, symptoms, and tolerance to certain exercises. Studies have shown that generalized vestibular exercises are not as successful as individualized and personal ones [817].

Computer and video games have been used for cognitive rehabilitation for patients with TBI [818]. Virtual rehabilitation purportedly may be beneficial for patient engagement and motivation [819-822]. Virtual reality utilizes computers as a way to enhance the activity of patients with TBI and inspire more real-life interaction [820, 822, 823].

VESTIBULAR REHABILITATION FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Vestibular rehabilitation is selectively recommended for patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Low

Indications

Patients with vestibular symptoms from TBI thought to be peripheral and not central in origin. Generally initiated with electronystagmogram (ENG). Not indicated for patients with concussion.

Benefits

Improved dizziness and balance problems.

Harms

Negligible.

Frequency/Dose/Duration

Twice weekly for 16 weeks (Kleffelgaard et al., 2019).

Indications for discontinuation

Completion of a course, noncompliance, or resolution of symptoms.

Rationale

Vestibular rehabilitation has been studied for the treatment of traumatic brain injury (Schlemmer et al., 2022, Aljabri et al., 2024, Babula et al., 2023, Galeno et al., 2022). One high-quality trial suggested efficacy of a vestibular rehabilitation program for treatment of dizziness and balance problems (Kleffelgaard et al., 2019, Søberg et al., 2021). Another moderate-quality trial suggested that cervicovestibular rehabilitation plus symptom-limited aerobic exercise program was superior to the exercise program alone for cervical and vestibular function (Langevin et al., 2022). Another moderate-quality study also suggested efficacy of vestibular rehabilitation for treatment of TBI (Schneider et al., 2014). There are multiple low-quality trials (Jafarzadeh et al., 2018, Tramontano et al., 2022).

Two systematic reviews concluded there was some evidence of efficacy and significant study heterogeneity (Aljabri et al., 2024, Galeno et al., 2022, Murray et al., 2017). Another concluded there was some evidence of faster return to sport (Babula et al., 2023).

Vestibular rehabilitation is not invasive, has no adverse effects, is moderate cost, has some evidence of treatment efficacy, and is recommended for selective treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: vestibular rehabilitation**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic,

systematic review, retrospective, and prospective studies. We found and reviewed 112 articles in PubMed, 32 in CINAHL, 29 in Cochrane Library, 20,300 in Google Scholar, and 2 from other sources†. We considered for inclusion 8 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 2 from other sources. Of the 10 articles considered for inclusion, 5 randomized trials and 5 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMPUTER AND VIDEO GAMES FOR BALANCE WITH TRAUMATIC BRAIN INJURY (TBI)

Recommended

Computer and video games for balance are recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Hemiparetic patients > 6 months attending a rehabilitation program, absence of cognitive impairment who are able to walk 10 meters indoors without orthopedic aids and are able to follow instructions.

Benefits

Improved balance.

Harms

Negligible.

Frequency/Dose/Duration

Two regimens have been used, either 2-hour long sessions, 3-5 times per week (Gil-Gomez et al., 2011) or 15-minute stand balance training for 4 weeks (Cuthbert et al., 2014).

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

There are two moderate-quality studies using video games (Cuthbert et al., 2014, Gil-Gomez et al., 2011). Both studies had small sample sizes. In one trial (Gil-Gomez et al., 2011), there was significant improvement in static balance and in another trial (Cuthbert et al., 2014), there was a weak positive trend towards increasing balance. A low-quality trial also suggested efficacy (Straudi et al., 2017).

Computer and video games are noninvasive, have low adverse effects, are moderate to high cost depending on supervision requirements and duration, and are recommended. However, larger studies need to substantiate the findings of the smaller pilot studies.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Computer OR video games; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 3,421 article in PubMed, 70 in CINAHL, 13 in Cochrane Library, 20,300 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 4 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VIRTUAL REALITY FOR BALANCE WITH TRAUMATIC BRAIN INJURY (TBI)

Recommended

Virtual reality for balance is recommended for use in the treatment of patients with TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Low

Indications

TBI patients who are physically able to use a VR system (be ambulatory), have good sitting balance, and have no perceptual disabilities that would prevent them from viewing the monitor where the virtual environment was displayed (Grealy et al., 1999).

Benefits

Improved memory, balance, reaction time, movement, visual and verbal learning tasks.

Harms

Falls in unstable patients, dizziness, otherwise negligible.

Frequency/Dose/Duration

3 times per week for 25 minutes for a total of 4 weeks (Grealy et al., 1999).

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

There are 11 moderate-quality studies, with most supporting modest efficacy (Cuthbert et al., 2014, Grealy et al., 1999, Jacoby et al., 2013, Yip et al., 2013, Man et al., 2013, Thornton et al., 2005, Fong et al., 2010, Jeong et al., 2024, De Luca et al., 2022, De Luca et al., 2019, Bruschetta et al., 2022). One trial found lack of superiority to a home exercise program (Tefertiller et al., 2019). Most of the studies had small sample sizes or sparse methods; thus, more trials are necessary to determine efficacy and clarify indications. There are multiple low-quality studies (Morris et al., 2023, De Luca et al., 2023, Tefertiller et al., 2022, Pennington et al., 2022, Ettenhofer et al., 2019). Systematic reviews indicate evidence of efficacy for balance, memory, executive function, attention, and mobility (Alashram et al., 2019, Alashram et al., 2022, Aulisio et al., 2020, Manivannan et al., 2019).

Virtual reality is noninvasive, has generally low adverse effects, and is high cost, but has evidence of efficacy; thus, it is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Virtual reality or VR**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 65 articles in PubMed, 1 in CINAHL, 45 in Cochrane Library, 17900 in Google Scholar, and 0 from other sources†. We considered for inclusion 12 from PubMed, 0 from CINAHL, 0 from Cochrane

Library, 3 from Google Scholar, and 0 from other sources. Of the 15 articles considered for inclusion, 10 randomized trials and 5 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

BODY WEIGHT SUPPORT TREADMILL TRAINING

Body weight support treadmill training (BWSTT) is a physical therapy technique to assist patients with limited or no walking ability to walk on a treadmill with his/her body weight supported by a harness connected to an overhead support system [824]. Those undergoing this treatment engage in high repetitions of task-oriented practices to improve motor skills and balance impairments [825]. Treadmill usage in turn allows progressive numbers of steps and increases the amount of task-specific practice a participant receives within one session [825].

BODY WEIGHT SUPPORT TREADMILL TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Body weight support treadmill training is recommended for use in the treatment of patients with TBI who have an inability to walk safely.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Inability to walk, or inability to walk safely while having sufficient patient abilities to move the lower extremities.

Benefits

Fosters faster return to walking ability, regain of muscle strength, and/or slower loss of strength.

Harms

Negligible.

Frequency/Dose/Duration

The optimum regimen needs to be tailored to the patient's abilities and stage of recovery. The two comparative trials used widely differing regimens: 15 minutes twice per week (Brown et al., 2005) and 45 minutes three times per week (Esquenazi et al., 2013).

Indications for discontinuation

Ability to walk with a walker, or to walk unassisted.

Rationale

There are no sham or placebo-controlled trials. There are a few quality comparative studies assessing body weight support treadmill training for treatment of TBI (Brown et al., 2005, Esquenazi et al., 2013), mostly showing comparable efficacy with other techniques. Body weight support treadmill training is not invasive, has negligible adverse effects, is high cost in aggregate, has evidence of efficacy, and thus is recommended for select treatment of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: body weight support treadmill**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 1 in CINAHL, 1 in Cochrane Library, 15,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 1 randomized trial and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COGNITIVE-MOTOR DUAL-TASKING

Patients with TBI often experience impairment in divided attention. Divided attention is required to perform multiple cognitive and motor tasks at a given time. Divided attention is also impaired by multiple sclerosis, stroke, Alzheimer's disease, and Parkinson's disease. Cognitive-motor dual-tasking, or walking and talking therapy has been used for treatment of patients with TBI [826].

COGNITIVE-MOTOR DUAL-TASKING FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation regarding cognitive-motor dual-tasking for use in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies of walking and talking therapy (or cognitive-motor dual-tasking). There is one trial of divided cognitive attention suggesting potential efficacy (Couillet et al., 2010), but not cognitive-motor. There is one low quality study suggesting a trend towards improvement (Evans et al., 2009). Cognitive-motor dual tasking is not invasive, has negligible adverse effects, is moderately costly, but has no quality evidence of efficacy and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Cognitive-motor dual testing**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 5 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 2,070 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

CONSTRAINT-INDUCED MOVEMENT THERAPY

Constraint-induced movement therapy is used to help regain function of an upper extremity after traumatic brain injury has caused a deficit [827]. There are three aspects on constraint induced movement therapy such as, forced use of affected hand while restraining intact hand, training by shaping movements by affected hand, and doing both at the same time [828]. Often a splint or a sling are used to restrain the hand. An increasing amount of

randomized controlled trials are being conducted within and outside the United States. Some studies are showing that longer CIMT sessions are showing more successful recovery.

CONSTRAINT-INDUCED MOVEMENT THERAPY FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Constraint-induced movement therapy is recommended for use in the treatment of patients with severe TBI who have limb function deficits.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Severe TBI patients with deficits in limb function.

Benefits

Faster improvement in use of the more affected limb.

Harms

Negligible.

Frequency/Dose/Duration

14 days of 6 hrs session was more effective than a 3hr session in one trial (Sterr et al., 2002). Frequencies of an ongoing program are unclear; thus, individualization is recommended.

Indications for discontinuation

Reaching an acceptable plateau of performance or lack of progression of objective measures would be a reason to stop the program.

Rationale

Constraint-induced movement therapy (CIMT) has been studied for the treatment of traumatic brain injury (Subramanian et al., 2022), with one moderate-quality study (Sterr et al., 2002). CIMT is not invasive, has no adverse effects, is moderate to high cost in aggregate, has evidence of treatment efficacy, and is recommended for select treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Constraint-Induced Movement Therapy; traumatic brain injury, intracranial injury, closed head injury,

penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 3 articles in PubMed, 0 in CINAHL, 1 in Cochrane Library, 1910 in Google Scholar, and 0 from other sources.† We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

EDUCATION PROGRAMS

Educational programs have been used in treatment of back, neck, eye, and respiratory disorder treatments. However, we found no quality evidence of use of educational programs to treat patients with traumatic brain injury.

EDUCATION PROGRAMS FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Education programs are recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Benefits

Improved understanding and compliance.

Harms

Negligible.

Rationale

Educational programs have been studied for the treatment of traumatic brain injury (Eliyahu et al., 2016, Fraas et al., 2016, Conaghan et al., 2021). Although there are many studies purportedly examining effects of education programs (Kroshus et al., 2019, Kneavel et al., 2020, Hanks et al., 2019, Echlin et al., 2010, Adame et al., 2023, Cusimano et al., 2014, Matuseviciene et al., 2013, Yao et al., 2020, Lu et al., 2023, McShan et al., 2023, Ymer et al., 2022), the overall literature base is noteworthy for varied interventions used, sparse

methods, details of interventions, and lack of assessments of durability rendering the literature base low quality. Systematic reviews noted similar problems (Conaghan et al., 2021, Eliyahu et al., 2016).

Education programs are not invasive, have no adverse effects, are low cost when education is incorporated in other rehabilitation programs, have no quality evidence of treatment efficacy, and are recommended as part of a rehabilitation plan for treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Education OR education programs; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 793 articles in PubMed, 26 in CINAHL, 227 in Cochrane Library, 437,000 in Google Scholar, and 0 from other sources†. We considered for inclusion 13 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 14 articles considered for inclusion, 11 randomized trials and 3 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

FUNCTIONALLY-BASED REHABILITATION

Functionally-based rehabilitation is a rehabilitation program that is centered on specific, functional requirements that include activities of daily living, work requirements and/or recreational needs [829]. Functionally-based rehabilitation has been used to improve day-to-day life for patients with severe TBI many years after injury [784, 810].

FUNCTIONALLY-BASED REHABILITATION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Functionally-based rehabilitation is recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Moderate, severe, chronic and postoperative patients with ongoing deficits in functional independence, anxiety and depression (Powell et al., 2002).

Benefits

Self-organization and psychological well-being.

Harms

Negligible.

Frequency/Dose/Duration

2 sessions per week of 2-6 hours per week for up to 27 weeks in patients with severe TBI.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

Psychosocial functioning and activity of daily living (ADLS) have been studied for the treatment of traumatic brain injury (Giles GM, 2019). One moderate quality study suggests an ADL retraining program after severe TBI is of benefit (Trevena-Peters et al., 2018). This intervention is not invasive, has negligible adverse effects, is moderate cost, has evidence suggesting efficacy and is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Activities of Daily Living; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 145 articles in PubMed, 135 in CINAHL, 43 in Cochrane Library, 17,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Of the 4 articles considered for inclusion, 3 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of

100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

HIGHER-ORDER REASONING TRAINING

Higher-order reasoning training has been used for treatment of patients with TBI, in large part to develop skills to determine the gist meanings of information [830, 831]. Higher-order reasoning training typically consists of short but intense programs that target the frontal lobe, which provides an integrative approach to train functionally relevant complex reasoning abilities [830, 831]. Specifically, the "top-down" approach has been developed by researchers to be deliberate in focusing on tasks that highlight the pre-frontal cortex in attention and task-relevant stimuli, while screening out irrelevant distractions [831]. Training frontal-mediated top-down processes in adults with TBI is theorized to be beneficial in restoring and improving higher-order cognitive functions [831].

HIGHER-ORDER REASONING TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

High-order reasoning training is recommended for treatment of patients with TBI who have problems with higher-order cognition.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients with TBI and problems with cognition.

Benefits

Improved cognition and executive function.

Harms

Negligible

Frequency/Dose/Duration

12 group sessions of 1.5 hours per session (Vas et al., 2011). Taught SMART strategies. Reading materials used.

Indications for discontinuation

Completion of a course of training, resolution of symptoms or noncompliance.

Rationale

Two moderate-quality RCTs suggest some efficacy of higher-order reasoning among patients with chronic TBI (Vas et al., 2011, Vas et al., 2016). Higher-order reasoning training is not invasive, has no significant adverse effects, is moderately costly, has evidence of efficacy, and is thus recommended for select patients.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: high order reasoning training; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 1 article in PubMed, 0 in CINAHL, 0 in Cochrane Library, 20,600 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 2 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

INPATIENT AND OUTPATIENT REHABILITATION PROGRAMS

There are numerous and diverse rehabilitation programs that have been developed. Some are inpatient, while some are outpatient [490, 832, 833]. Some are based in acute care facilities, while others rehabilitation facilities and still others specialize in patients with TBI. Some programs have a single or few components (e.g., physical therapy and medical services), while others are integrated/multidisciplinary and include many other services (e.g., psychology/mental health, vocational rehabilitation, occupational therapy, substances abuse treatment/prevention, social work). Not all patients need all program components, so regardless of the setting, tailoring of the program to the specific patient's needs is required. Multidisciplinary programs are generally more comprehensive and may be more indicated with more severe injuries with greater degrees of various impairments. Selective and integrated rehabilitation programs are designed to help the individual work on specific tasks in order to "retrain" the body to accomplish said task [834]. Some programs focus on TBI while others may focus on an array of neurological and orthopedic conditions [835]. This section will classify these heterogenous programs into only the two categories of inpatient and outpatient for ease of use.

For those with TBI rehabilitation typically consists of an individualized program of rehabilitation therapies delivered most often by an integrated interdisciplinary team with at least two components (e.g., medical and therapy). Most programs have many more

components, especially those targeting the TBI patient population and some are multi-disciplinary [832, 833, 836].

OUTPATIENT HOME AND COMMUNITY-BASED REHABILITATION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Outpatient home and community-based rehabilitation is selectively recommended for patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Sufficient residual symptoms and/or signs after TBI to necessitate ongoing treatment, be it medical, physical therapy, occupational therapy, or other. These programs are generally more helpful for those with greater numbers and magnitudes of mismatch between current abilities and job cognitive and physical demands. There may be select cases with mild TBI with ongoing symptoms who may be candidates.

Benefits

Ongoing treatment targeting functional outcomes to improve the patient's overall prognosis. Improved likelihood *o*f achieving goals including RTW.

Harms

Negligible.

Frequency/Dose/Duration

The frequence of appointments is highly variable and depends on the clinical status, including symptoms, signs, functional deficits, rate of progress, need for individualized care (e.g., coaching), etc. The frequencies of appointments are most typically 2-3 times a week, but may be as frequent as daily in individual cases needing more intensive care.

Indications for discontinuation

Sufficient recovery, end of healing, reaching a plateau, noncompliance, substance use, recalcitrant recidivism.

Rationale

The overall literature base is weak, as there are quality studies assessing components of rehabilitation programs, but no quality studies assessing whether these programs are superior to no treatment or to sham. Outpatient home and community-based rehabilitation

is not invasive, has negligible adverse effects, is high cost, is thought to be quite effective, and thus is recommended for selective treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Outpatient home and community-based rehabilitation; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 7370 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

INPATIENT COMPREHENSIVE INTEGRATED INTERDISCIPLINARY REHABILITATION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Inpatient comprehensive integrated interdisciplinary rehabilitation is selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Sufficient residual symptoms and/or signs of mostly acute TBI to necessitate ongoing and daily treatment, be it medical, physical therapy, occupational therapy, or other. Most programs are multidisciplinary, and generally TBI inpatients are sufficiently severely affected to require multidisciplinary services. Most patients will have incurred severe TBI; occasionally, patients with moderate TBI may also be benefited by these programs. Generally not used for chronic TBI unless the TBI was severe and the patient is making functional gains that are not possible or substantially less likely to occur in an outpatient setting.

Benefits

Ongoing treatment targeting functional outcomes to improve the patient's overall prognosis. Improved likelihood of achieving goals, including return to work.

Harms

Negligible.

Frequency/Dose/Duration

Highly variable and depends on the clinical status, including symptoms, signs, functional deficits, rate of progress, need for individualized care (e.g., coaching), etc.

Indications for discontinuation

Sufficient recovery to be able to be discharged to outpatient facilities.

Rationale

The overall literature base is weak, as there are quality studies assessing select components of inpatient rehabilitation programs, but no quality studies assessing whether these programs are superior to no treatment or to sham. Inpatient comprehensive integrated rehabilitation is not invasive, has negligible adverse effects, is high cost, and is thought to be quite effective. Therefore, it is recommended for selective treatment of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Comprehensive Integrated Interdisciplinary Rehabilitation; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 9 in CINAHL, 0 in Cochrane Library, 15800 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MEMORY AND MOTOR IMAGERY

Memory rehabilitation is a form of cognitive rehabilitation with the goal to improve memory retrieval. Those with traumatic brain injury may utilize memory rehabilitation to assist in restoration of normal brain function. Typically, various memory techniques are used, which include computer and non-computer-based. Memory and reasoning tasks are used as cognitive rehabilitation utilizing accepted methods in patients with TBI [837, 838]. Some specific methods include computer memory retaining groups, games, and reasoning tasks. Computer memory retraining has been used to treat patients with TBI [839, 840]. Handheld computers have been used by patients with TBI to assist in memory [841].

Restorative imagery training has been used to treat patients with TBI to facilitate independent functioning [842]. Imagery skills include TDMI screening test, temporal congruence stepping test, walking trajectory test, and hand mental rotation test [843, 844]. Cognitive rehabilitation is a type of therapy that is used to attempt to improve function within the brain after central nervous system accidents [551]. It uses multimedia to focus on similar neuropsychological processes and train the brain to do particular functions [551]. Cognitive rehabilitation uses therapeutic activities such as restorative functional skills, and memory training purportedly helps patients recover from traumatic brain injuries [845, 846]. Repetition of a certain activity is used to improve recovery in patients after brain injury [847]. However, repetitive training is a time-consuming process and patients often report boredom [847]. Play-based interventions to stimulate enjoyment is one approach being used to overcome such difficulties [847].

MEMORY REHABILITATION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Memory rehabilitation is recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Memory problems after TBI. May be selectively indicated for patients with mild TBI with significant memory deficits.

Benefits

Improved recall and memory.

Harms

Negligible.

Indications for discontinuation

Completion of a course of training, resolution of symptoms or non-compliance.

Rationale

There is one high-quality trial suggesting efficacy (Chiaravalloti et al., 2023). Another trial found improvements at 6 months that did not persist to 12 months (das Nair et al., 2019). Other moderate-quality studies are also supportive (Twamley et al., 2014, Lannin et al., 2014). However, there are many diverse interventions that are used across the studies. There also are low-quality studies (Cisneros et al., 2021). Memory rehabilitation is not invasive, has negligible adverse effects, has evidence of efficacy, and thus, these treatments are recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Memory Rehabilitation; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 265 articles in PubMed, 8 in CINAHL, 91 in Cochrane Library, 18000 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 3 randomized trials and 0 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MEMORY/REASONING TASKS OR GAMES FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation regarding memory/reasoning tasks or games for patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are only low-quality studies, with one suggesting some benefit from computer games on memory performance (Dou et al., 2006). This intervention is not invasive, has negligible

adverse effects, and is moderate cost. Without quality evidence of efficacy, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Memory tasks OR reasoning tasks OR games OR video games; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 301 article in PubMed, 168 in CINAHL, 137 in Cochrane Library, 19,800 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMPUTER MEMORY RETRAINING GROUP (CMRG) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Computer memory retraining group is recommended for use in the treatment of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

Patients with moderate, severe, postop, chronic TBI, with at least one functional hand to interact with computer demands without evidence of psychiatric disorders, post injury substance abuse, no premorbid neurological disorders, sufficient vision and cognitive function.

Benefits

Improved memory functions.

Harms

Negligible.

Frequency/Dose/Duration

2 hour sessions per day for 20 total hours.

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

There is one moderate-quality study (Ruff et al., 1994) and one low-quality study (Tam et al., 2004) showing CMRG improves memory retraining. This treatment is noninvasive, has negligible adverse effects, is moderate-high cost and has evidence suggesting efficacy; therefore, it is recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: computer assisted memory retaining group OR CMRG; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 17,900 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SMART TECHNOLOGY (HANDHELD COMPUTERS) AS MEMORY AIDS FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of handheld computers/smart technology for the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Moderate

Rationale

Handheld computers have been studied for the treatment of traumatic brain injury (Kettlewell et al., 2019). A high-quality trial suggested superior performance on memory goals after use of a handheld computer (Lannin et al., 2014). Several moderate-quality trials suggest efficacy (Elbogen et al., 2019, Belanger et al., 2022), while others suggest lack of efficacy/superiority (Gracey et al., 2017, De Joode et al., 2013). There are low-quality trials (Ramirez-Hernandez et al., 2022, Ramirez-Hernandez et al., 2023). A systematic review concluded there was insufficient evidence for the use of personal smart technologies for treatment of patients with TBI (Kettlewell et al., 2019). Handheld technological aids are not invasive, have no adverse effects, are high cost, have unclear evidence of efficacy, and thus there is no recommendation for treatment of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Computers, Handheld; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 21 article in PubMed, 1 in CINAHL, 3 in Cochrane Library, 17,400 in Google Scholar, and 0 from other sources†. We considered for inclusion 7 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 6 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

RESTORATIVE IMAGERY TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Restorative imagery training is selectively recommended for patients with severe TBI.

Strength of evidence Moderately Recommended, Evidence (B)
Level of confidence Moderate

Indications

Patients with severe, postoperative, chronic TBI with ongoing deficits approximately 8 years post injury with a mean GCS of about 5.

Benefits

Improved memory and learning functions in addition to improved motor imagery (Oostra et al., 2012).

Harms

Negligible.

Frequency/Dose/Duration

2 sessions per week 45-60 minutes long using imagery from Story Memory Technique (mSMT) for 5 weeks (Chiaravalloti et al., 2015).

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

There is one high-quality study on restorative imagery training for memory improvement that suggests improved memory and learning (Chiaravalloti et al., 2015). There is one moderate-quality study (Oostra et al., 2012) showing some benefit in restoration of motor imagery. Restorative imagery training is noninvasive, has negligible adverse effects, is moderate-high cost, and has evidence suggesting efficacy; therefore, it is moderately recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Restorative imagery training, Image restoration, Motor imagery; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 1 in CINAHL, 10 in Cochrane Library, 4000 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

RESTORATIVE FUNCTIONAL SKILLS TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for the use of restorative functional skills training in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies on restorative functional skills training. Restorative functional skills training is noninvasive, has negligible adverse effects, and is moderate-high cost. In the absence of evidence of efficacy, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: restorative functional skills training**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 2 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 18,200 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

GAMES, ART, AND SELF-EXPRESSION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Games, art, and self-expression are recommended for use in the treatment of TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients between 1 and 7 years post-TBI. Evidence is best for patients with mild TBI (Ryan et al., 1988) but patients with more severe TBI are thought to potentially benefit.

Benefits

Improved memory function.

Harms

Negligible.

Frequency/Dose/Duration

Six weeks of 4 days per week of 5.5 hours of training (psychological and neuropsychological) for a total of 6 weeks (Ryan et al., 1988).

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

There is one moderate-quality study involving the use of games, art, and self-expression techniques, which suggested modest efficacy (Ryan et al., 1988). These treatments are noninvasive, have negligible adverse effects, are low cost when self-administered, and are recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: games, art, and other forms of self expression; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 196 articles in PubMed, 162 in CINAHL, 0 in Cochrane Library, 238,000 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we

review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

COMPUTER-ASSISTED COGNITIVE REHABILITATION FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Computer-assisted cognitive rehabilitation is selectively recommended for the treatment of patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Moderate

Indications

Patients 3-6 months post injury with moderate cognitive dysfunction (more marked in language production, visual attention, memory span and other memory abilities such as immediate recall). Most patients showed unilateral hemispheric lesions via MRI (De Luca et al., 2010).

Benefits

Improved memory span, cognition and other memory functions.

Harms

Negligible.

Frequency/Dose/Duration

24 sessions of pre-cognitive training 3 times per week times 8 weeks has been used. Alternately, a self-administered computerized cognitive training program has also been used at home under online supervision via a healthcare coach for 1 hour daily, 5 days a week for 13 weeks total (Mahncke et al., 2021).

Indications for discontinuation

When desired improvement has been achieved, clinical plateau or failure to improve.

Rationale

Computer-assisted cognitive rehabilitation (CACR) has been studied for the treatment of traumatic brain injury (Alashram, 2024, Fernández López et al., 2020). Multiple moderate-quality studies suggest improvements in cognition (Vanderploeg et al., 2008, De Luca et al., 2014, Lundqvist et al., 2010, Mahncke et al., 2021, Hwang et al., 2020). One trial

(Vanderploeg et al., 2008) found short-term but not long-term improvement in global outcomes at 1 year.

While another trial found no improvements in memory (Ishida et al., 2023), a meta-analysis found improvements in visual working memory (Fernández López et al., 2020). There are low-quality trials (Tam et al., 2004, Ruff et al., 1990, Batchelor J, 1988, Dou et al., 2006). Restorative and compensatory computer-assisted cognitive rehabilitation is not invasive, has negligible adverse effects, is high cost as administered in the highest quality trial, and with nearly all studies suggesting efficacy, it is selectively recommended.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: computer-assisted cognitive rehabilitation**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 19 articles in PubMed, 18 in CINAHL, 2 in Cochrane Library, 8,810 in Google Scholar, and 1 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MUSCLE TONE AND JOINT RESTRICTION MANAGEMENT

Severe damage to the central nervous system, of various origin, often causes severe spasticity [848-855].

MUSCLE TONE AND JOINT RESTRICTION MANAGEMENT FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for muscle tone and joint restriction management in patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Muscle tone and joint restriction management has been studied for the treatment of traumatic brain injury (Synnot et al., 2017, Subramanian et al., 2022). One trial found no additive benefit of electrical stimulation plus ankle splints to tilt table standing alone (Leung et al., 2014). There are low-quality reports (Pittaccio et al., 2013, Pattuwage et al., 2017). A Cochrane review concluded the overall evidence was very low and no firm conclusions about the benefits could be drawn (Synnot et al., 2017).

Muscle tone and joint restriction management (including spasticity) is not invasive, has negligible adverse effects, and is moderate to high cost in aggregate. However, in the absence of quality evidence, there is no recommendation for this specific approach for treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Muscle tonus, muscle tone**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 10 articles in PubMed, 6 in CINAHL, 3,898 in Cochrane Library, 18,100 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 4 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 9 articles considered for inclusion, 4 randomized trials and 4 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

MUSIC THERAPY

Music therapy is clinical use of music intended to be a therapeutic intervention. Music therapy has been used in rehabilitation to stimulate brain functions involved in movement, cognition, speech, emotions, and sensory perceptions [856, 857].

MUSIC THERAPY FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Music therapy is recommended for the treatment of select patients with TBI.

Strength of evidence Recommended, Evidence (C)

Level of confidence Low

Indications

Patients with moderate to severe TBI and executive function impairments and/or gait impairments.

Benefits

Improved executive function, improved gait disturbance.

Harms

Negligible.

Frequency/Dose/Duration

60-min sessions, 2 times/week for 3 months (Siponkoski et al., 2022, Siponkoski et al., 2020).

Indications for discontinuation

Completion of a course, resolution of symptoms, noncompliance.

Rationale

Music therapy has been studied for the treatment of traumatic brain injury (Magee et al., 2017, Mishra et al., 2021, Alashram et al., 2023, Ghai, 2023). A moderate-quality crossover trial reported efficacy of music therapy for improving executive function (Siponkoski et al., 2022, Siponkoski et al., 2020, Sihvonen et al., 2022, Martínez-Molina et al., 2021, Martínez-Molina et al., 2022). Another trial (Lynch, 2016) had sample sizes so small (4-5 patients per group) that there were nonsignificant results.

A few studies have suggested institution of music stimulation in comatose patients has benefits (Yekefallah et al., 2021, Froutan et al., 2020). A Cochrane review noted the evidence is generally of low quality, but supportive for efficacy through use of rhythm to improve walking ability, although it addresses patients who incurred strokes (Magee et al., 2017). A meta-analysis of low-quality studies reported evidence that music therapy improved stride length and executive function in patients with TBI (Mishra et al., 2021).

Music therapy is not invasive, has no adverse effects, is moderate cost in aggregate, has some limited evidence of efficacy, and thus is recommended for treatment of TBI for patients with executive function and gait disturbances.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Music Therapy; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 19 articles in PubMed, 4 in CINAHL, 6 in Cochrane Library, 4980 in Google Scholar, and 0 from other sources†. We considered for inclusion 6 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 9 articles considered for inclusion, 5 randomized trials and 4 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

NEUROMUSCULAR RE-EDUCATION

Neuromuscular re-education is a therapy used to restore normal movement and function. The therapy uses simple repetitive movements of joints, weight bearing, resistance, and variable speed and length of therapy (North American Spine Society). The application of neuromuscular reeducation for treatment of traumatic brain injury is unknown.

NEUROMUSCULAR RE-EDUCATION FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of neuromuscular re-education in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies assessing neuromuscular re-education for treatment of TBI, and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: neuromuscular re-education**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled

trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 0 articles in PubMed, 10 in CINAHL, 0 in Cochrane Library, 1810 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1810 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

NEUROPLASTICITY

Neuroplasticity is the brain's capacity to change and adapt. It refers to the physiological changes in the brain that happen as a result of our interactions with our environment. Neuroplasticity is a definite factor in recovery from brain injury. It is the basis for much of our cognitive physical rehabilitation practices.

NEUROPLASTICITY FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation regarding targeting neuroplasticity for patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Neuroplasticity has been studied for the treatment of traumatic brain injury (Calderone et al., 2024). Literature has suggested neuroplasticity is important for improving the prognosis of patients with TBI and suggests differing approaches, including targeting inflammation and cognitive training (see other interventions) (Calderone et al., 2024, Han et al., 2020). However, literature on a targeted approach to neuroplasticity does not support an evidence-based recommendation for one specific intervention/approach, and thus there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: neuroplasticity, neural plasticity; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic,

systematic review, retrospective, and prospective studies. We found and reviewed 58 articles in PubMed, 3 in CINAHL, 5 in Cochrane Library, 19,600 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 1 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 1 randomized trial and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

OCCUPATIONAL AND PHYSICAL THERAPY

Occupational and physical therapy are professional disciplines. The ACOEM Guidelines do not recommend a discipline; rather, the guidelines review quality evidence in support of successful treatment interventions that may be employed by physical and occupational therapists and other professionals. However, there are many interventions that physical and occupational therapists institute that have evidence of efficacy (see other guidance).

REACTION TIME TRAINING

Reaction time tests (arm movement reaction time, hand response with different levels of difficulty) have been used for saccadic deficits after severe head trauma [858-861].

REACTION TIME TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against reaction time training for TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

Reaction time training has been studied for the treatment of traumatic brain injury (Lempke et al., 2020), but there are no quality studies assessing the treatment. Thus, in the absence of quality evidence, there is no recommendation for or against reaction time training for TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: reaction time training; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma;

controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 682 articles in PubMed, 36 in CINAHL, 13 in Cochrane Library, 18,600 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 1 from CINAHL, 0 from Cochrane Library, 18,600 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

READING COMPREHENSION EXERCISES

Reading comprehension is one of the difficulties in patients with TBI [862, 863] and is one of the skillsets that has been included in TBI rehabilitation programs [863].

READING COMPREHENSION EXERCISES FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of reading comprehension exercises in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality trials to address success, content, frequency, or intensity of reading exercises for TBI. There is one moderate-quality trial suggesting simplified emergency department discharge instructions for head injury are preferable, but this does not test rehabilitation and was for patients with mild TBI (Yates et al., 2006). Yet, systematic reviews note the importance of reading skills (Pei et al., 2021, Rowley et al., 2017, Watter et al., 2017). Reading comprehension exercises are not invasive, have no adverse effects, are low cost, and are thought to be helpful. However, in the absence of quality evidence, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: TREATMENT TOPIC**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury,

concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 14 articles in PubMed, 2 in CINAHL, 0 in Cochrane Library, 19,900 in Google Scholar, and 2 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

RESIDENTIAL REHABILITATION

There are many options for treatment facilities for someone with a severe TBI. One of these is a nursing care facility. These facilities are also known as nursing homes or skilled nursing facilities (SNF). These facilities provide medical care to patients 24 hours a day and can treat those suffering acute or chronic conditions [(864)]. Residential rehabilitation facilities are used for treatment of patients with TBI [(865)]. Residential rehabilitation has been used as a treatment option for those who have had a traumatic brain injury and are seeking treatment. It is a program that is separate from home and inpatient care. Supported living programs or long-term care residential services are used for patients that require long-term care or rehabilitation [(866, 867)]. These are generally less intensive than skilled nursing facilities. With TBI, occupational rehabilitation may be helpful particularly for rehabilitating the patient toward the goal of return to work (RTW). Opioid/Chemical treatment programs have been used for treatment of substances use patients [(868-870)]. They are a heterogenous group of treatment programs ranging from detoxification to 24-hr. residential treatment facilities. There is one study suggesting potential efficacy for purposes of prevention [(871)].

RESIDENTIAL REHABILITATION FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Residential rehabilitation is selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Sufficient residual symptoms and/or signs of post TBI to necessitate ongoing outpatient treatment, be it medical, physical therapy, occupational therapy, or other. Generally these programs are used for those with more numerous impairments, an inability to return-to-home unassisted, and/or greater numbers and magnitudes of mismatch between current abilities and ADLs, job cognitive, and physical demands.

Benefits

Ongoing treatment targeting functional outcomes to improve the patient's overall prognosis. Improved likelihood of achieving goals including ADLs and RTW.

Harms

Negligible

Frequency/Dose/Duration

Highly variable and depends on the clinical status, including symptoms, signs, functional deficits, rate of progress, need for individualized care (e.g., coaching), etc. Daily unskilled or skilled care is generally needed.

Indications for discontinuation

Sufficient recovery, end of healing, reaching a plateau, non-compliance.

Rationale

There are no quality studies assessing residential rehabilitation programs. These programs are not invasive, have negligible adverse effects, are high cost, are thought to be effective, and thus are recommended for selective treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Residential rehabilitation**;** traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 38 articles in PubMed, 1 in CINAHL, 26 in Cochrane Library, 18,900 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SUPPORTED LIVING PROGRAMS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Supported living programs are selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Severe TBI with sufficient impairments and inabilities to, e.g., perform ADLs, but insufficient for a skilled nursing facility that assisted living is required. Most patients needing supported living programs will have incurred severe TBI, but occasionally, select patients with moderate TBI with significant impairments and incapacity may also be benefited by these programs.

Benefits

Ability to receive tailored assistance. May be able to receive sufficient care to achieve independence and discharge to either home or a lower level of skilled care.

Harms

Potential for nosocomial infections. May also be in a facility that does not sufficiently accelerate the rehabilitative process, thus impairing achievement of treatment goals.

Indications for discontinuation

Recovery sufficient to not require.

Rationale

There are no quality studies assessing supported living programs (SLPs) for treatment of TBI. SLPs are not invasive, have significant risks of problems such as nosocomial infections, and are high cost. For select patients with severe TBI, there may be no other practical alternative; thus, skilled care SLPs are selectively recommended for some patients with severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Supported Living Programs, Supportive Living Facilities, Assisted Living; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and

prospective studies. We found and reviewed 62 articles in PubMed, 2 in CINAHL, 67 in Cochrane Library, 21300 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

SKILLED NURSING FACILITIES FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Skilled nursing facilities are selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Severe TBI with sufficient impairments and inabilities to perform ADLs that a skilled nursing facility if needed.

Benefits

Ability to receive tailored assistance. May be able to receive sufficient care to achieve independence and discharge to either home or a lower level of skilled care.

Harms

Potential for nosocomial infections. May also be in a facility that does not sufficiently accelerate the rehabilitative Process, thus impairing achievement of treatment goals.

Indications for discontinuation

Recovery sufficient to not require.

Rationale

There are no quality studies assessing skilled nursing facilities for treatment of TBI. Nursing care facility treatment is not invasive, has significant risks of problems such as nosocomial infections, and is high cost. For select patients with severe TBI, there may be no other practical alternative. Thus, skilled care facilities are selectively recommended for some patients with severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Skilled Nursing Facilities, SNF; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled

trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 26 articles in PubMed, 3 in CINAHL, 2 in Cochrane Library, 18600 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

OPIOID/CHEMICAL TREATMENT PROGRAMS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Opioid/chemical treatment programs are selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Substance abuse sufficient to require opioid and/or chemical treatment programs, including withdrawal, anticipated high-risk withdrawal, medical condition, emotional factors, behavioral factors, cognitive aspects, recurrences, and degrees of addictions.

Benefits

Avoidance of substance use, managed withdrawal to reduce fatalities and other severe effects of withdrawal.

Harms

Negligible. May incur complications from treatment especially with medications.

Indications for discontinuation

Completion of treatment.

Rationale

There are no quality studies assessing opioid/chemical treatment programs for treatment of patients with TBI. They are not invasive, may not have significant adverse effects (other than medication treatment complications), are high cost, do not have evidence of treatment efficacy for patients with TBI, but are likely effective for select patients with substance use disorder. Thus, they are thus recommended for treatment of select patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Opioid or Chemical treatment programs, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 101 articles in PubMed, 0 in CINAHL, 0 in Cochrane Library, 20,800 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

ROBOTICS

Rapidly emerging innovative technologies for rehabilitation include robotics [872]. Robotic devices includes end-effector and exoskeleton devices that allow paraplegics and quadriplegics to walk, sometimes referred to as locomotor training with robotic assistance and robotic-assisted gait training [825, 873-875].

ROBOTICS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Robotics are recommended for use in the treatment of select patients with TBI.

Strength of evidence Recommended, Evidence (C)
Level of confidence Moderate

Indications

Reached a plateau such that not able to walk without robotic assistance, also having sufficient interest and motivation.

Benefits

Ability to ambulate, although current technology allows for only a slow, somewhat ratcheting gait.

Harms

Potential for falls.

Indications for discontinuation

Falls, inability to tolerate, disinterest, disuse.

Rationale

There are two moderate-quality RCTs studies using robotics for treatment of TBI (Esquenazi et al., 2013, Susanna Freivogel, 2009). One trial reported greater walking distance and no need for second therapists for training sessions with a robotic device compared with locomotor training (Susanna Freivogel, 2009). Another trial reported mostly comparable efficacy with manually-assisted treadmill training (Esquenazi et al., 2013). There also are numerous successes of wheelchair-bound patients regaining the ability to walk (Giulia Stampacchiaa et al., 2016, Andrej Olenšek, 2016, Sale P, 2016, Jeffrey R. Koller, 2015, Kristel Knaepen et al., 2015, Dennis R. Louie, 2015, Li et al., 2015, L. Wallarda, 2015, Yang et al., 2015, Hartigan C, 2015, Carolyn Buesing et al., 2015) and there is one RCT in stroke patients (Carolyn Buesing et al., 2015). Systematic reviews suggested efficacy (Bonanno et al., 2022, de Miguel-Fernández et al., 2023).

Robotics treatment is not invasive, has modest adverse effects, is very high cost, but has mostly empiric evidence of treatment efficacy, and is recommended for treatment of select patients with severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: robotics; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 84 articles in PubMed, 36 in CINAHL, 6 in Cochrane Library, 17,900 in Google Scholar, and 0 from other sources†. We considered for inclusion 4 from PubMed, 0 from CINAHL, 1 from Cochrane Library, 9 from Google Scholar, and 0 from other sources. Of the 14 articles considered for inclusion, 6 randomized trials and 5 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles,

we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SPECIFIC MOTOR STIMULATION

Specific motor stimulation has been used to treat hand impairments from stroke or TBI [876].

SPECIFIC MOTOR STIMULATION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Specific motor stimulation is recommended for use in the treatment of patients with moderate to severe TBI who have notable impairment of at least one extremity.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Moderate to severe TBI injuries with notable impairment of at least one extremity. The quality study had entry criteria of <80% score on the Action Research Arm Test (Ross et al., 2009).

Benefits

Improved functional rehabilitation of an extremity.

Harms

Negligible.

Frequency/Dose/Duration

One-hour session daily, 5 days per week for 6 weeks.

Rationale

There is one moderate-quality trial suggesting specific motor stimulation is effective for rehabilitation of patients; however, 90% of the subjects were stroke patients (Ross et al., 2009). Specific motor stimulation is not invasive, has low adverse effects, and is high cost in aggregate. Although some evidence suggests it may be effective, the population was not primarily patients with TBI; thus, it is recommended by consensus.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Specific motor stimulation OR motor stimulation**;** traumatic brain injury, intracranial injury, closed head

injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 134 articles in PubMed, 8 in CINAHL, 92 in Cochrane Library, 19,600 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SYSTEMATIC INSTRUCTION

Systematic instruction is a multiple component system for teaching skills and other information based on a specific method. Systematic instruction has been used for rehabilitation of acquired brain injury [877, 878].

SYSTEMATIC INSTRUCTION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Systematic instruction is recommended for the treatment of patients with TBI with moderate to severe cognitive impairments.

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

TBI patients with moderate to severe cognitive impairments.

Benefits

Improved learning that is better than trial-and-error learning.

Harms

Negligible.

Rationale

There is one moderate-quality trial of moderate-severe TBI patients suggesting systematic instruction is more effective than trial-and-error learning for rehabilitation of patients with TBI (Powell LE, 2012). Systematic instruction is not invasive, has no adverse effects, is low to

moderate cost in aggregate, has evidence of efficacy, and is recommended for treatment of patients with TBI with moderate to severe cognitive impairments.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Systematic instruction; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 121 article in PubMed, 0 in CINAHL, 34 in Cochrane Library, 19,200 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

TELEVISION-ASSISTED REHABILITATION

Television-assisted rehabilitation has been used for treatment of patients with TBI by prompting reminders on a TV [879, 880].

TELEVISION-ASSISTED REHABILITATION FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Television-assisted rehabilitation is recommended for use in the treatment of patients with TBI. However, the panel vote was split (50% of panel members supported Recommended (C) and 50% supported No Recommendation (I)).

Strength of evidence Recommended, Evidence (C)
Level of confidence Low

Indications

TBI impacts that limit completion of tasks at home, for which reminders are likely helpful (Lemoncello et al., 2011).

Benefits

Improved task completion. May be usable to remind to complete exercises or cognitive exercises.

Harms

Negligible.

Rationale

Television assisted rehabilitation has been studied for the treatment of traumatic brain injury (Ownsworth et al., 2023). There is one moderate-quality trial of television-assisted rehabilitation for treatment of acquired brain injury patients that suggested some efficacy (Lemoncello et al., 2011). Television-assisted rehabilitation is not invasive, has no adverse effects, is moderate to high cost, has some evidence of efficacy and is thus recommended for treatment of patients with TBI (Lemoncello et al., 2011). However, the panel vote was split with 50% in support of recommended and 50% in support of no recommendation (I).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Television Assisted Rehabilitation, Television Assisted Promotion, Telerehabilitation; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 17 articles in PubMed, 6 in CINAHL, 5 in Cochrane Library, 19300 in Google Scholar, and 0 from other sources†. We considered for inclusion 0 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VIDEO FEEDBACK ON TASK PERFORMANCE

Video feedback on task performance has been used for treatment of patients with TBI [881, 882]. Decreased self-awareness is suggested to occur due to a number of neuroanatomical as well as cognitive impairments [883, 884].

VIDEO FEEDBACK ON TASK PERFORMANCE FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Video feedback on task performance is recommended for use in the treatment of patients with severe TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

Patients with task performance problems after severe TBI. The quality trial used meal preparation as the outcome (Schmidt et al., 2011, Schmidt et al., 2015), although the approach appears applicable to occupational task performance.

Benefits

Potential to improve accuracy of task performance.

Harms

Negligible.

Frequency/Dose/Duration

Meal task performance was accomplished on 4 occasions in the quality study with subsequent self- and therapist-videotape reviews and verbal feedback (Schmidt et al., 2011, Schmidt et al., 2015).

Rationale

One moderate-quality trial with two reports suggested a combination of video feedback with verbal was superior to either approach alone (Schmidt et al., 2011, Schmidt et al., 2015), Video feedback plus verbal training is not invasive, has negligible adverse effects, is moderate to high cost in aggregate, has some potential evidence of effectiveness and thus is recommended for selective treatment of patients with severe TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Video feedback OR task performance feedback; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 24 articles in PubMed, 1 in CINAHL, 67 in Cochrane Library, 19,800 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we

review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

WHOLE BODY VIBRATION

Whole body vibration is a therapeutic technique most commonly used in physical injuries to improve muscular functions by placing a patient on a vibrating platform [885, 886]. Whole body vibration has been used to treat spinal cord injuries, knee osteoarthritis, muscle tears, and many more muscle related injuries [886, 887].

WHOLE BODY VIBRATION FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against the use of whole body vibration in the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are no quality studies assessing whole body vibration for treatment of TBI. Whole body vibration is not invasive, has minimal adverse effects, is moderately costly in aggregate, but has no quality evidence of efficacy, and thus there is no recommendation for treatment of TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Whole body vibration OR WBV; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 1 article in PubMed, 0 in CINAHL, 5 in Cochrane Library, 15,700 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

VISION TRAINING

There is a high incidence (greater than 50%) of visual and visual-cognitive disorders in patients with neurological impairments (traumatic brain injury, cerebral vascular accidents, multiple sclerosis etc.) [888]. Visual difficulties after traumatic brain injury (TBI) are common and often difficult to recognize. Oculomotor dysfunctions are also among the most common vision problems in individuals with acquired brain injury (ABI). Visual training has been used for treatment of neurological deficits; however the randomized studies of size are mostly of stroke patients [889, 890]. One study evaluated improvements in visual search among hemianopic patients [889], while the other compared explorative saccade and flicker training in hemianopic patients [890-894]. Oculomotor training has been used, especially in military settings, for rehabilitation from TBI [895].

VISION TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

No Recommendation

There is no recommendation for or against vision training for the treatment of patients with TBI.

Strength of evidence No Recommendation, Insufficient Evidence (I)
Level of confidence Low

Rationale

There are only low-quality studies and/or studies with small sample sizes (of mostly patients who experienced a stroke) assessing vision training in patients with TBI (Keller et al., 2010, Roth et al., 2009, Thiagarajan, 2013, Thiagarajan et al., 2014, Thiagarajan et al., 2014, Thiagarajan et al., 2014, Berger et al., 2016). Thus, there is no recommendation.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Vision training; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 154 articles in PubMed, 6 in CINAHL, 48 in Cochrane Library, 18,700 in Google Scholar, and 0 from other sources†. We considered for inclusion 1 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 article considered for inclusion, 0 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of

100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

OCULOMOTOR TRAINING FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Oculomotor training is recommended for the treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Low

Indications

TBI with accommodative dysfunction of at least 6 months duration.

Benefits

Identification and treatment of accommodative dysfunction related to TBI.

Harms

Negligible.

Frequency/Dose/Duration

Two 60-minute sessions/week for 9 sessions total (Thiagarajan et al., 2014).

Indications for discontinuation

Resolution, completion of a course of treatment.

Rationale

Oculomotor training has been studied for the treatment of traumatic brain injury (Sheeba et al., 2023). There is one moderate-quality trial in the military suggesting efficacy of oculomotor training for rehabilitation of mild TBI (Thiagarajan et al., 2014). Another study is underpowered (Berryman et al., 2020). Oculomotor training is not invasive, has negligible adverse effects, is low to moderate cost in aggregate, has some evidence of efficacy in military settings, and thus is recommended for select treatment of patients with TBI.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Oculomotor Training, Oculomotor Dysfunction Training, Oculomotor Vision Treatment; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled

trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 98 articles in PubMed, 15 in CINAHL, 4 in Cochrane Library, 9860 in Google Scholar, and 0 from other sources†. We considered for inclusion 2 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 1 randomized trial and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

SURGICAL CONSIDERATIONS

OPERATIVE AND SURGICAL PROCEDURES

There are no specific surgical recommendations because the requirements of the individual patient are wide-ranging and beyond the scope of this guideline.

The patient with TBI may require surgery, particularly during the acute stage depending upon the individual injury mechanism and clinical presentation [(896)]. Many of these procedures occur in the setting of severe TBI. However, especially in older workers, surgical evacuations of subdural and epidural hemorrhages are more common and do not necessarily occur solely with severe TBI and/or loss of consciousness. Thus, those cases may technically be classified as mild TBI based on loss of consciousness criteria, but also classified as severe based on requiring neurosurgery. Attention to the clinical presentation, an understanding of the demographic group's risk factors, and careful attention to the clinical course are required to detect many of these cases.

There are numerous procedures used on patients with TBI, and these are patient-specific and require physician discretion. It is not within the scope of this guideline to provide all potential surgeries. Common procedures include:

- Craniectomy for elevated intracranial pressure relief
- Cranioplasty [(897)]
- Debridement
- Decompression of nerves
- Evacuation of fluids
- Lumbar drains for cerebrovascular fluid (CSF) leaks or CSF fistula
- Maxillofacial fracture surgeries (including maxillofacial surgery, repairs, reconstruction and releases) [(898, 899)]
- Nerve repair/reconstruction/release
- Orthopedic surgeries for fractures
- Rhizotomy for spasticity as well as intrathecal baclofen (see)
- Soft tissue repairs
- Relief of vascular occlusions

- Ventricular shunting
- Ventriculostomy for ICP and obstructive hydrocephalus

RETURN TO WORK

Return to work (RTW) is considered to be a major challenge for patients affected by TBI [193, 900-907], as it is for return to sports [51, 407, 491, 900, 908-914]. RTW differs considerably based on the severity of the TBI and the patient's specific residual deficits, if any.

The challenges and barriers to RTW differ between mTBI (where there are rarely long-term neurological impairments) versus moderate and severe TBI (where chronic physical, cognitive, and psychological sequelae are prominent). Furthermore, maximal medical recovery is often not achieved for up to 1-2 years postinjury in moderate-severe TBI cases. Most estimates are that less than 50% of moderate to severely affected patients achieve employment [199, 902], and one estimate was under 10% [915]. Thus, return to work is considered an important part of rehabilitation after TBI since being employed is typically associated with better quality of life and self-worth for TBI survivors [901]. Factors associated with higher RTW rates are unclear, but generally thought to include shorter hospital stay, and shorter rehabilitation stays [916-918] which would also appear likely confounded by injury severity [907], younger age , multiple body injuries and increased severity of TBI [315]. Yet, Glasgow Coma Scale Scores have not been found predictive [918-921] nor have anxiety or depression [907, 916, 921-923].

Decision-making and success of RTW among workers may be difficult as there are reported problems with reliability of the history and physical examination for decision-making that may impact return to work determinations [134, 136, 139, 140, 151]. Chief among these is likely under-reporting of pre-injury symptoms, psychological conditions, alcohol use, and drug use that is problematic in studies that independently assessed pre-morbid medical records [136, 140].

Decision-making may also be potentially difficult as there are reported problems with effort on physical examination and/or neuropsychological evaluation [227, 161, 164]. It has been suggested that this is addressable through: optimize expectations [217], (2) treat depression and anxiety, (3) minimize stereotype threat, (4) addressing anger and revenge, (5) address loss aversion, and (6) consider possible effects of compensation on behavior [227].

By contrast, decision-making among highly motivated patients, such as athletes, may be difficult due to the underreporting of symptoms [924-928].

RETURN TO WORK/ACTIVITY FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

For patients with TBI, return to work or activities without a significant risk of repeat TBI is recommended, generally earlier than later (Waljas et al., 2014).

Strength of evidence Recommended, Evidence (C)
Level of confidence Moderate

Indications

All patients. The speed of return to work (RTW) and activities, if possible, is based on the patient's current cognitive and physical status as compared with the job's cognitive and physical demands. Most patients with mild TBI may generally be immediately returned to work in some capacity. Close follow-up can be utilized to adjust work activities as tolerated. Additionally, pre-injury conditions such as alcohol and drug use and the preexistence of psychological conditions and pre-existing pain have been shown to be recalled at significantly lower rates in comparison with preinjury medical records (Don et al., 2009). Underreporting of pre-injury symptoms is reportedly problematic (Iverson et al., 2010, Don et al., 2009).

Yet, especially with progressively more severe TBI, decision-making may be difficult as there are reported problems with reliability for decision-making that may impact diagnosis, treatment and return to work (Barth, 2009, Iverson et al., 2010, Don et al., 2009). RTW decisions among those with moderate to severe TBI involve identification and quantification of deficits which are then compared with job requirements. The greater the gap between the patient's current capabilities and the job demands, the more likely there is a need for: 1) job modifications (e.g., temporary elimination of a difficulty job task), 2) alternate job assignment, 3) stepwise transitioning into ever more demanding jobs, and/or 4) further rehabilitation to target identified gaps.

RTW for those with safety-critical jobs (e.g., those requiring personal/corporate vehicle operation, rail, overhead crane use, transportation/traffic control, forklift operation; positions with high cognitive/judgment demand (e.g., nuclear plant worker, public safety officer)) requires incorporation of an assessment of seizure history and risk as well as cognitive ability to make critical determinations with minimal processing time. History of seizures further impacts return to safety-sensitive jobs. Driving ability among those both in the general driving population as well as particularly among those projected to return to safety-sensitive jobs having incurred moderate to severe TBI may require neuropsychological testing (Egeto et al., 2019, Korteling et al., 1996, Schneider et al., 2005, Cyr et al., 2009, Coleman et al., 2002) and on-road driving assessments (McKay et al., 2016, Korteling et al., 1996). On-road driving assessments may be particularly necessary in this population due to significant overestimations of the driving performance of patients with TBI (Gooden et al., 2017). Cognitive impairments may impair the ability to return to safety-critical jobs both concerning driving abilities as well as judgment and decision-making. The development of epilepsy precludes many safety-critical jobs, including pilots and most truck drivers. For truck drivers having epilepsy defined as having had at least two seizures, absence of seizures for at least 8 years on or off anti-epileptics is generally required to be licensed by the Federal Motor Carrier Safety Administration.

For those with jobs requiring exercising of judgment and/or executive demands beyond the current capacity may require added cautions about the speed of RTW to those demanding tasks. Among more severely affected workers, graded transitional programs (cognitive and/or physical, as indicated) and gradually increasing hours of work should be strongly considered. Tailoring of the limitations and lengths of shifts with consideration of graded transitional work positions are strong considerations.

Benefits

Potential to improve clinically faster based on return to work earlier, improvements in self-worth.

Harms

May result in some frustration if the job demands substantially exceed the patient's capabilities. Mismatches may require readdressing. Patients with known, or high probability of seizures are unlikely to be appropriate tor return to their prior occupation other than perhaps after many years (Sinclair DC 2nd, 2021).

Rationale

A systematic review with meta-analysis reported that 42.2% of patients incurring moderate-severe TBI were employed postinjury and 33% were in their pre-morbid job (Gormley et al., 2019); thus, loss of work and earnings are considerable. For patients with mild TBI, another systematic review with meta-analysis found that RTW rates were higher, but 44% of patients remained off work at 1 month and 17% remained off work at 6 months (Bloom et al., 2018). Predictors of RTW in another systematic review were identified as including employment status at time of TBI, occupation, Glasgow Coma score, length of stay, disability level, and primary payer (Van Deynse et al., 2022, Pietrapiana et al., 2005).

A moderate-quality RCT found no adverse effects for earlier graduated vs. delayed return to work (Varner et al., 2017). A trial in pediatric patients found worse outcomes among those assigned to strict rest compared with the usual care group, suggesting strict rest is not helpful. An RCT comparing 6 months of compensatory cognitive training and supported employment (CCT-SE), with treatment as usual for mild to moderate TBI, found the CCT-SE intervention group returned to work earlier (Fure et al., 2023, Fure et al., 2021, Howe et al., 2020). A brief phone intervention was found to be effective compared with CBT for early follow-up of patients with at-risk mild TBI (Scheenen, 2017). Trials reported short-term superiority of an in-hospital cognitive rehabilitation program to a limited home rehabilitation program for RTW at 1 year (Salazar et al., 2000, Vanderploeg et al., 2008).

One moderate-quality trial assessing whether the use of resource facilitation is helpful for RTW found efficacy of those services; please see vocational rehabilitation section below (Trexler et al., 2010). That trial may provide some indirect evidence that earlier RTW may be effective. There are no trials for any disorder in any of the ACOEM Guidelines showing superiority of delayed return to work; thus, earlier return to work is widely recommended for other disorders.

Systematic reviews are also relatively sparse (Saltychev et al., 2013, Donker-Cools et al., 2016, Bloom et al., 2018), while also suggesting that psychiatric disorders are strong negative factors for RTW (Garrelfs et al., 2015). Executive function problems/cognition also predict reduced RTW (Aliaga et al., 2024, Mani et al., 2017).

Return-to-sports literature is similarly sparse and, overall, of low quality. One low-quality study of 1,228 NCAA athletes found earlier return to exercise was associated with faster recovery among those having had a concussion (Lempke et al., 2023). A systematic review concluded there is no quality evidence that return to sport alters prognosis (Cancelliere et al., 2023). Another systematic review concluded that early light physical activity within 2 days and prescribed aerobic exercise days 2-14 with reduced screen use the first 2 days are associated with improved recovery (Leddy et al., 2023) and other studies suggest earlier return to learning among students is beneficial (Brown et al., 2015, McCrea et al., 2020, Thomas DG, 2015). Return to sport after structural injuries is more controversial and expert recommendations are highly heterogeneous (Zuckerman SL, 2021). However, some studies also suggest full participation in sports after a concussion is associated with longer duration of symptoms and delayed recovery (Eagle SR, 2022, Elbin RJ, 2016, Asken BM, 2018). Quality evidence indicates that strict rest is not recommended.

Return to work and low-intensity non-contact sports is noninvasive, has few adverse effects, is low cost, has some quality evidence of efficacy, and thus is recommended. RTW often requires tailoring to the specific worker, their limitations, and specific job demands. Return to low-intensity, noncontact sports is generally tailored to the symptoms. A successful strategy may include an earlier return to prescribed aerobic exercise within the first 2 weeks (see Activity Modification and Exercise recommendations).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Return To Work; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 25 articles in PubMed, 0 in CINAHL, 10 in Cochrane Library, 17900 in Google Scholar, and 4 from other sources†. We considered for inclusion 11 from PubMed, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 4 from other sources. Of the 15 articles considered for inclusion, 6 randomized trials and 9 systematic reviews met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

FUNCTIONAL CAPACITY EVALUATIONS

While most commonly used for evaluation of spine and extremity disorders, functional capacity evaluations have been used to assess patients with TBI [(929)]. Functional capacity evaluations are a set of tests, observations and practices that are combined to attempt to

ascertain the ability of the patient to function most commonly either in one discrete job (e.g., return to work after injury) or potentially in a wide variety of different employment settings without targeting one in particular. A functional capacity evaluation is used to infer the work capacity [930]. A FCE may also be used to ascertain a baseline from which to develop a treatment program, to target specific work return to work needs [931-933]. The goals of FCEs include:

- Determine individual's readiness to work after injury or illness at Maximum Medical Improvement (MMI),
- Assist with goal-setting and treatment planning for rehabilitation or to monitor the progress of a patient in a rehabilitation program,
- Estimate potential vocational status and provide a foundation for effective vocational rehabilitation,
- Provide information to assist in disability determinations,
- Provide information for hiring decisions (post-offer or fit-for-duty testing),
- Assess the extent of disability in litigation cases, and
- Provide information regarding a patient's level of effort and consistency of performance.

FUNCTIONAL CAPACITY EVALUATIONS (FCES) FOR TRAUMATIC BRAIN INJURY (TBI)

Recommended

Functional capacity evaluations (FCEs) are recommended for the evaluation of disabling TBI sequelae, when the information may be helpful for determining worker capability, function, motivation, and effort with regard to either a specific job or general job requirements. In circumstances when a patient with moderate to moderately severe TBI is not progressing as anticipated at 6 to 8 weeks, an FCE can evaluate functional status and patient performance in order to match performance to specific job demands, particularly in instances where those demands are medium to heavy. If a clinician is comfortable describing work ability without an FCE, there is no requirement to do this testing. However, our panel vote was split (62% of panel members supported Recommended (I) and 38% supported of No Recommendation (I)).

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Benefits

Assess functional abilities and may facilitate greater confidence in return to work.

Harms

Medicalization, worsening of pain with testing. May have misleading results that understate capabilities. May be particularly misleading if the FCE does not assess job-specific cognitive aspects, yet those are the patient's primary difficulties.

Rationale

FCEs are one of the few means to attempt to objectify limitations and are frequently used in workers' compensation systems, particularly as the correlation between pain ratings and functional abilities appears weak (Brouwer S, 2005, Eriksen J, 2006, Gross DP, 2003, Reneman MF, 2002, Reneman MF, 2007, Schiphorst Preuper HR, 2008, Smeets RJ, 2007). Yet, obtaining objective data regarding either TBI or spine problems is somewhat more challenging than for extremity-related impairments due to the degree of reliance on the patient's subjective willingness to exert or sustain major activities (e.g., standing, walking, sitting) that are critical for job performance. As FCEs typically emphasize physical over cognitive performance, FCEs are also typically somewhat limited in their ability to assess most patients with TBI. Those that combine job-specific cognitive with physical assessments may be better able evaluate, assess and guide the return to work and rehabilitative processes. Because their reliability and validity have not been proven, FCEs should be utilized to evaluate work ability about what a patient was willing to do on a given day. They should not be used to override the judgment about the work ability of a patient with a TBI or spine problem. It may be important to note that the expert panel vote was split with 62% in support of a favorable recommendation (I) and 38% in support of no recommendation (I).

Many commercial FCE models are available. There is research regarding inter-and intra-rater reliability for some of the models (complete discussion is beyond the scope of this guideline). The validity of FCEs, particularly predictive validity, is more difficult to determine, since factors other than physical performance may affect return to work (Gouttebarge V, 2004, Pransky GS, 2004). An FCE may be done for one or more reasons, including identifying an individual's ability to perform specific job tasks associated with a job (job-specific FCE) and physical activities associated with any job (general FCE), or to assist in the objectification of the degree(s) of impairment(s). The type of FCE needed, and any other issues the FCE evaluator needs to address, should be specified when requesting an FCE.

The term "capacity" used in FCE may be misleading, since an FCE generally measures an individual's voluntary performance rather than his or her capacity. Physical performance is affected by psychosocial as well as physical factors. The extent of an individual's performance should be evaluated as part of the FCE process through analysis of his or her level of physical effort (based on physiological and biomechanical changes during activity) and consistency of performance. Perhaps more importantly, the objective findings identified in the musculoskeletal evaluation should correlate with any identified functional deficits. The individual's performance level, especially as it relates to stated levels of performance, should be discussed in the FCE report. A properly performed and well-reported FCE will highlight such discrepancies. This is particularly important in TBI and cervicothoracic evaluations where there may be greater degrees of impairments at stake and where there are somewhat fewer metrics available than for the distal upper extremity.

FCE test components may vary depending on the model used, but most contain the following:

- Patient interview including:
- Informed consent
- Injury/illness and medical history
- Current symptoms, activities and stated limitations
- Pain ratings/disability questionnaires

- Musculoskeletal examination (e.g., including Waddell's non-organic signs)
- Observations throughout the session (e.g., demonstrated sitting tolerance, pain modifying behaviors)
- Material handling tests (lifting, carrying, pushing, pulling)
- Movement tests (walking, crouching, kneeling, reaching, etc.)
- Positional tolerance tests
- Dexterity/hand function
- Static strength (varies among models)
- Aerobic fitness (usually submaximal test-also variable among models)
- Job specific activities as relevant
- Reliability of client reporting (e.g., non-organic signs, pain questionnaires, placebo tests, etc.)
- Physical effort testing (e.g., Jamar Dynamometer maximum voluntary effort, bell curve analysis, rapid exchange grip, competitive test performance, heart rate, observation of clinical inconsistencies, etc.)

FCE test length may vary between FCE models, although most 1-day FCEs are completed in 3 to 4 hours. Two-day tests, where the patient is seen on 2 consecutive days, may be recommended when there are problems with fatigue (e.g., chronic fatigue syndrome), delayed onset of symptoms, unusually complex job demands to simulate, and questions about symptom validity. Test length for 2-day tests is generally 3 to 4 hours on the first day, and 2 to 3 hours on the second day.

Interpretation of FCE results is complicated in that it is a measure of voluntary performance. Before beginning testing, the patient is counseled to avoid doing anything to knowingly reinjure him or herself. Thus "fear avoidance" may cause testing to seriously underestimate actual ability and result in a report that the patient had "self-limited performance due to pain, " suggesting a low pain tolerance, when in reality the patient was doing what he or she was instructed.

The best studies on the ability of FCEs to predict safe re-entry to the workplace following rehabilitation of work-related back pain/injury suggest that FCEs are not able to predict safe return to work (concurrent validity) (Gross DP, 2004, Gross DP, 2005, Gross DP, 2004). In a prospective cohort study of 1,438 consecutive work-related back patients, all underwent a FCE prior to return to work. In the control group, the FCE was used to write return-to-work guidelines, while in the study group it was ignored and the worker was returned usually to full duty. Ignoring the FCE reportedly improved outcomes in a 1994 study, although the results have not been duplicated (Hall H, 1994) and the quality of an FCE is believed to be heavily dependent on the skill, knowledge and experience of the FCE evaluator (Wind H, 2009).

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Functional capacity evaluation OR FCE; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral

trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 85 articles in PubMed, 0 in CINAHL, 16 in Cochrane Library, 18,200 in Google Scholar, and 0 from other sources†. Zero articles met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

JOB SITE EVALUATIONS

Job site evaluations are used for many purposes that include ascertainment of job requirements (as job descriptions are typically inadequate for job-specific return-to-work analyses), measurement of specific exposures, measurement of job performance abilities, analyses of potential movement to another position, ability to reduce job limitations on the job, planning rehabilitation program targets and components, and prevention of secondary injuries. Any of these are appropriate uses of job site evaluations and for which they are selectively recommended. Development of relationships with all key workplace members is often essential for successful placements of more severely injured workers, and on-site visits help to foster these working relationships.

Ideally, an initial review of a written job description is performed that will help to both: 1) focus the quantifications of the patient's current abilities that are relevant to the job and 2) formulate a preliminary list of job demands to be focused upon during a job site evaluation. Because written job descriptions are naturally quite limited in their ability to define job demands, especially with more complex jobs and cognitive demands, an initial phone call with a supervisor is often helpful.

Examples of common reasons to conduct an on-site evaluation include the following:

1. Quantify physical and cognitive demands for the injured worker's original job and also the job projected to be the RTW position. Those quantified job demands then inform a therapeutic exercise plan (including cognitive components) to quantify any gaps between current abilities and targeted requirements, which are then translated into a therapeutic exercise plan. These quantified demands and the gaps between current abilities and job requirements also may be used to help motivate the patient regarding their progress, as well as naturally informing the timelines of part-time or full-time RTW.
2. Identify potential alternate jobs that a patient may be able to perform, either as a permanent job position or as part of a stepped transitioning plan to a more demanding job.

These quantifications can also help to determine the potential need for work hardening/work conditioning.

VOCATIONAL REHABILITATION PROGRAMS

Because return to work (RTW) can be problematic, many different vocational rehabilitation (VR) programs have been utilized. These are thought to have been effective in assisting

patients with TBI in the recovery and RTW processes [193, 901, 904, 934, 935]. The components of VR programs utilized vary, but usually include elements sometimes classified as: case-coordination-based, program-based and supported employment [934]. Case-coordination involves assessing job requirements and referring for services including job training and vocational counseling [936]. Program-based includes intensive individualized work skills rehabilitation, guided work trials and assisted placement with transitional job support [915, 934]. Supported employment includes job placement, on-the-job training and long-term support for job skills with on the-job coaching Wehman [934, 937-940].

VOCATIONAL REHABILITATION PROGRAMS FOR TRAUMATIC BRAIN INJURY (TBI)

Sometimes Recommended

Vocational rehabilitation programs are selectively recommended for treatment of patients with TBI.

Strength of evidence Recommended, Insufficient Evidence (I)
Level of confidence Moderate

Indications

Many patients with severe TBI and occasional moderate TBI. Vocational rehabilitation programs are generally more helpful for those with greater mismatch between current abilities and job cognitive and physical demands.

Benefits

Potential to improve faster based on earlier return to work.

Harms

Negligible other than program cost.

Rationale

Vocational rehabilitation has been studied for the treatment of traumatic brain injury (Manoli et al., 2021). There is one moderate-quality trial reporting efficacy of the use of resource facilitation for return to work (Trexler et al., 2010). One low-quality study noted the feasibility of embedding cognitive rehabilitation within vocational rehabilitation for mild TBI (O'Connor et al., 2016). Another low-quality study reported success with including resource facilitation in vocational rehabilitation in a larger study population (Trexler et al., 2018). A third low-quality study found a combined cognitive and vocational rehabilitation program to be cost-effective for patients with mild-to-moderate TBI (Howe et al., 2022). A systematic review noted a lack of linkage between cognitive and behavioral functioning with vocational outcomes, while opining the link is important (Manoli et al., 2021). Vocational rehabilitation programs are noninvasive, have negligible effects, are moderate cost, and are likely effective, and thus are recommended. They require tailoring to the specific worker and their limitations.

Evidence

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Rehabilitation, Vocational; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective, and prospective studies. We found and reviewed 90 articles in PubMed, 6 in CINAHL, 8 in Cochrane Library, 20,400 in Google Scholar, and 0 from other sources†. We considered for inclusion 3 from PubMed, 0 from CINAHL, 8 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 3 randomized trials and 1 systematic review met the inclusion criteria.

† The results for databases are sorted by relevancy based on customized search term algorithms. Algorithms for each database determine relevancy. The first 100 articles are reviewed in each search, and if relevant literature appears in the first 100 articles, we review an additional 100 articles. If relevant articles appear in these additional 100 articles, we then review another 100. We continue this pattern of review until we review a batch of 100 articles that contains no relevant literature. When this happens then the remaining articles are not reviewed due to a lack of relevancy.

PROGNOSIS

The prognosis for patients with TBI is naturally correlated with the severity of the TBI event [162, 308, 480, 941-943]. Markers for prognosis include durations of loss of consciousness and posttraumatic amnesia [308]. Military and civilian populations have been found to have few long-term sequala of TBI after accounting for PTSD [129, 168, 944].

Yet, a study of 40-year population-based data from Sweden showed an approximately 3-fold elevated risk of mortality among patients with TBI (or a 2.6-fold adjusted risk compared with unaffected siblings). Other elevated risks included 3.3-fold for suicide, 4.3-fold for injuries, 3.9-fold for assaults, and higher risks among those with psychiatric or substance abuse comorbidities [796].

Persistence of symptoms after TBI has been shown to be increased in those who are older [138, 150, 151], female [149, 152], and had a more severe injury [138, 150, 151, 153]. Persistence of symptoms has been associated with alcohol [140, 150], drug use [140, 150], psychological/psychiatric history [140, 146, 150, 152], seeking compensation [146] and lower socioeconomic status [154] [135, 141, 163, 166-171, 945]. Similar findings of worse outcomes with lower parental education, school achievement, and a history of learning problems, have been reported in pediatric patients with TBI [138, 151, 155].

Many patients with mild TBI have been reported to have signs of exaggerating the duration and severity of symptoms, especially with secondary gain considerations that include workers compensation or litigation [162, 478]. Assessment of effort has been reported to be a major problem in evaluation of subacute to chronic TBI cases, especially when the TBI was

mild [160-164]. Perceived injustice after mild TBI is associated with worse prognosis [946]. Routine attribution of neurobehavioral symptoms to a prior TBI event is a reported risk for worse prognosis [947].

Effort has been reported to be more important than TBI injury severity [160-165]. Similarly, a patient's perception of adverse consequences after mild TBI and/or stress are also important in the ongoing perception of symptoms persistence [135, 141, 163, 166, 167]. Lower rates of return-to-work status have been reported among those who are older, had a lower Glasgow Coma Score, had extremity injuries, had prior job instability, and have lower education [172].

Full recovery is expected after mild TBI [145, 151, 162, 170, 303, 490, 943, 948, 949], with expected full recovery in 1 to 3 months [137, 303, 478, 480, 483, 913, 950]. By contrast, most improvements in moderate to severe TBI occur over the first 1 to 2 years, but may persist beyond or indefinitely, particularly with severe injuries [213, 304, 480, 941]. There is far less quality literature on repeated TBI events, nearly all of which involves athletes; quality data substantially conflict regarding whether there are worse cognitive or degenerative outcomes and prognoses with multiple TBIs [951, 952, 953] despite the attention this is receiving in the lay press.

FOLLOW-UP VISITS

It is recommended that patients with work-related mild to moderate TBI should follow-up in person or by phone every 1 to 5 days with a clinician who can offer subsequent assessments and counseling regarding assessments for complications (e.g., subdural hematomas), advancing cognitive activity levels, advancing physical activities, avoiding inactivity, medication use, anticipated favorable prognosis, and other concerns [**Recommended Insufficient Evidence (I)**]. Those with moderate to severe TBI may require hospitalization and some will require intensive care monitoring and treatments [**Recommended Insufficient Evidence (I)**].

Interactive sessions should typically actively involve the patient in his or her recovery. If the patient has returned to work, these interactions may be conducted on site or by telephone to avoid interfering with work activities. Subsequent follow-up can occur when there is need for: 1) altered treatment; 2) release to modified, increased, or full duty; or 3) after appreciable healing or recovery can be expected. Typically, this will be no later than 1 week into the acute pain period.

When a patient has residual and stable sequalae of TBI, less frequent follow-up is needed. Achievement of stability generally takes a minimum of 2 years. Regardless of apparent stability, more frequent follow-up may be needed when there is a move to the next level of functioning, e.g., when an individual is ready to re-enter the work force well down the line post-injury. In that context of re-integrating into the work force, follow-up is frequently of benefit and more frequent follow-up during that transitioning period may be of benefit to work through transitioning, accommodations, and fear avoidant beliefs.

After 2 years, and when there is complete stability, follow-up may be infrequent, such as every 6 months, unless there is functional transitioning noted above. Depending upon the complexity of the case and the TBI complications, outpatient follow-up visits may be needed more frequently, approximately every 3-6 months. Mostly stable patients may generally be

seen 4-6 times per year due to their TBI co-morbidities, with more frequent and individualized follow-ups needed for complex and/or less stable patients.

APPENDIX 1. PICO(T) QUESTIONS

1.

P—Workers and/or patients with TBI

I—Skull x-rays

C—Is there evidence that skull x-rays are superior to other diagnostic tools?

O—Identification/diagnosis of TBI

2.

P—Workers and/or patients with TBI

I—Computerized tomography (CT)

C—Is there evidence that CT is superior to other diagnostic tools?

O—Identification/diagnosis of TBI

3.

P—Workers and/or patients with TBI

I—Magnetic resonance imaging (MRI)

C—Is there evidence that MRI is superior to other diagnostic tools?

O—Identification/diagnosis of TBI

4.

P—Workers and/or patients with TBI

I—Magnetic resonance spectroscopy (MRS)

C—Is there evidence that MRS is superior to other diagnostic tools?

O—Identification/diagnosis of TBI

5.

P—Workers and/or patients with TBI

I—Functional magnetic resonance imaging (fMRI)

C—Is there evidence that fMRI is superior to other diagnostic tools?

O—Identification/diagnosis of TBI

6.

P—Workers and/or patients with TBI

I—Diffusor tension imaging (DTI)

C—Is there evidence that DTI is superior to other diagnostic tools?

O—Identification/diagnosis of TBI

7.

P—Workers and/or patients with TBI

I—Single photon emission computerized tomography (SPECT)

C—Is there evidence that SPECT is superior to other diagnostic tools?

O—Identification/diagnosis of TBI

8.

P—Workers and/or patients with TBI

I—Positron emission testing (PET)

C—Is there evidence that PET is superior to other diagnostic tools?

O—Identification/diagnosis of TBI

9.

P—Workers and/or patients with TBI

I—Vascular imaging tests

C—Are vascular imaging tests superior to other diagnostic tools?

O—Identification/diagnosis of TBI

10.

P—Workers and/or patients with TBI

I—Brain acoustic monitoring (BAM)

C—Is BAM superior to other diagnostic tools?

O—Identification/diagnosis of TBI

11.

P—Workers and/or patients with TBI

I—Electroencephalography (EEG)

C—Is EEG superior to other diagnostic tools?

O—Identification/diagnosis of TBI

12.

P—Workers and/or patients with TBI

I—Quantitative electroencephalography (qEEG)

C—Is qEEG superior to EEG or other diagnostic tools?

O—Identification/diagnosis of TBI

13.

P—Workers and/or patient with TBI

I—Somatosensory evoked potential (SSEP)

C—Is SSEP superior to other diagnostic tools?

O—Identification/diagnosis of TBI

14.

P—Workers and/or patients with TBI

I—Vestibular evoked myogenic potentials

C—Are vestibular evoked myogenic potentials superior to other diagnostic tools?

O—Identification/diagnosis of TBI

15.

P—Workers and/or patients with TBI

I—Electromyography (EMG)

C—Is EMG superior to other diagnostic tools?

O—Identification/diagnosis of TBI

16.

P—Workers and/or patients with TBI

I—Nerve conduction studies

C—Are nerve conduction studies superior to other diagnostic tools?

O—Identification/diagnosis of TBI

17.

P—Workers and/or patients with TBI

I—Electroneuronography (EnoG)

C—Is EnoG superior to other diagnostic tools?

O—Identification/diagnosis of TBI

18.

P—Workers and/or patients with TBI

I—Ultrasonography (US)

C—Is US superior to other diagnostic tools?

O—Identification/diagnosis of TBI

19.

P—Workers and/or patients with TBI

I—Neurocognitive testing

C—Is neurocognitive testing superior to other diagnostic tools?

O—Identification/diagnosis of TBI

20.

P—Workers and/or patients with TBI

I—Neurological assessment

C—Is neurological assessment superior to other diagnostic tools?

O—Identification/diagnosis of TBI

21.

P—Workers and/or patients with TBI

I—Automated neuropsychological assessment metrics (ANAM)

C—Is ANAM superior to other diagnostic tools?

O—Identification/diagnosis of TBI

22.

P—Workers and/or patients with TBI

I—Cognitive event related potential

C—Is the use of cognitive event related potential superior to other diagnostic tools?

O—Identification/diagnosis of TBI

23.

P—Workers and/or patients with TBI

I—Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)

C—Is ImPACT superior to other post-concussion tools?

O—Identification/diagnosis of TBI

24.

P—Workers and/or patients with TBI

I—King Devick testing

C—Is King Devick testing superior to other post-concussion tools?

O—Identification/diagnosis of TBI

25.

P—Workers and/or patients with TBI

I—Military Acute Concussion Evaluation (MACE)

C—Is the MACE superior to other concussion evaluations?

O—Identification/diagnosis of TBI

26.

P—Workers and/or patients with TBI

I—Sport Concussion Assessment Tool (SCAT)

C—Is the SCAT superior to other concussion evaluation

O—Identification/diagnosis of TBI

27.

P—Workers and/or patients with TBI

I—Standardized Assessment of Concussion (SAC)

C—Is the SAC superior to other concussion evaluation

O—Identification/diagnosis of TBI

28.

P—Workers and/or patients with TBI

I—Attention tests

C—Are Attention tests superior to other diagnostic tools?

O—Identification/diagnosis of TBI

29.

P—Workers and/or patients with TBI

I—Executive function tests

C—Are executive function tests superior to other diagnostic tools?

O—Identification/diagnosis of TBI

30.

P—Workers and/or patients with TBI

I—Memory tests

C—Are memory tests superior to other diagnostic tools?

O—Identification/diagnosis of TBI

31.

P—Workers and/or patients with TBI

I—Minnesota Multiphasic Personality Inventory (MMPI)

C—Is the MMPI superior to other diagnostic tools?

O—Identification/diagnosis of TBI

32.

P—Workers and/or patients with TBI

I—Wechsler Adult Intelligence Scale (WAIS, WAIS-III)

C—Are the WAIS or WAIS-III superior to other diagnostic tools?

O—Identification/diagnosis of TBI

33.

P—Workers and/or patients with TBI

I—Wechsler Memory Scale III (WMS-III)

C—Is the WMS-III superior to other diagnostic tools?

O—Identification/diagnosis of TBI

34.

P—Workers and/or patients with TBI

I—Tests of memory malingering

C—Are memory malingering tests superior to other diagnostic tools?

O—Identification/diagnosis of TBI

35.

P—Workers and/or patients with TBI

I—Visual acuity testing

C—Is visual acuity testing superior to other diagnostic tools?

O—Identification/diagnosis of TBI

36.

P—Workers and/or patients with TBI

I—Visual evoked potential (VEP)

C—Is VEP superior to other diagnostic tools?

O—Identification/diagnosis of TBI

37.

P—Workers and/or patients with TBI

I—Visual field testing

C—Is visual field testing superior to other diagnostic tools?

O—Identification/diagnosis of TBI

38.

P—Workers and/or patients with TBI

I—Visual perceptual testing

C—Is visual perceptual testing superior to other diagnostic tools?

O—Identification/diagnosis of TBI

39.

P—Workers and/or patients with TBI

I—Electroretinogram (REG)

C—Is ERG superior to other diagnostic tools?

O—Identification/diagnosis of TBI

40.

P—Workers and/or patients with TBI

I—Fluorescein antibody

C—Is fluorescein antibody superior to other diagnostic tools?

O—Identification/diagnosis of TBI

41.

P—Workers and/or patients with TBI

I—Optical coherence tomography

C—Is optical coherence tomography superior to other diagnostic tools?

O—Identification/diagnosis of TBI

42.

P—Workers and/or patients with TBI

I—Audiometry

C—Is audiometry superior to other diagnostic tools?

O—Identification/diagnosis of TBI

43.

P—Workers and/or patients with TBI

I—Brainstem audiometry evoked response

C—Is brainstem audiometry evoked response superior to other diagnostic tools?

O—Identification/diagnosis of TBI

44.

P—Workers and/or patients with TBI

I—Tympanometry

C—Is tympanometry superior to other diagnostic tools?

O—Identification/diagnosis of TBI

45.

P—Workers and/or patients with TBI

I—Vestibular function testing

C—Is vestibular function testing superior to other diagnostic tools?

O—Identification/diagnosis of TBI

46.

P—Workers and/or patients with TBI

I—Computerized dynamic platform posturography

C—Is computerized dynamic platform posturography superior to other diagnostic tools?

O—Identification/diagnosis of TBI

47.

P—Workers and/or patients with TBI

I—Electronystagmography (ENG) or video nystamography (VNG)

C—Are either ENG or VNG superior to other diagnostic tools?

O—Identification/diagnosis of TBI

48.

P—Workers and/or patients with TBI

I—Rotary chair testing

C—Is rotary chair testing superior to other diagnostic tools?

O—Identification/diagnosis of TBI

49.

P—Workers and/or patients with TBI

I—Cognitive-motor dual testing

C—Is cognitive-motor dual testing superior to other diagnostic tools?

O—Identification/diagnosis of TBI

50.

P—Workers and/or patients with TBI

I—Family visits

C—Are family visits equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

51.

P—Workers and/or patients with TBI

I—Multimodal and unimodal coma stimulation

C—Are multimodal or unimodal coma stimulation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

52.

P—Workers and/or patients with TBI

I—Action sequences

C—Are action sequences equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

53.

P—Workers and/or patients with TBI

I—High order reasoning training

C—Is high order reasoning training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

54.

P—Workers and/or patients with TBI

I—Vision training

C—Is vision training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

55.

P—Workers and/or patients with TBI

I—Reading comprehension

C—Is reading comprehension equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

56.

P—Workers and/or patients with TBI

I—Specific motor comprehension

C—Is specific motor comprehension equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

57.

P—Workers and/or patients with TBI

I—Systematic instruction

C—Is systematic instruction equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

58.

P—Workers and/or patients with TBI

I—Television assisted rehabilitation

C—Is television assisted rehabilitation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

59.

P—Workers and/or patients with TBI

I—Handheld computers for memory aids

C—Are handheld computers equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

60.

P—Workers and/or patients with TBI

I—Physical therapy

C—Is physical therapy equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

61.

P—Workers and/or patients with TBI

I—Occupational therapy

C—Is occupational therapy equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

62.

P—Workers and/or patients with TBI

I—Strengthening exercises

C—Are strengthening exercises equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

63.

P—Workers and/or patients with TBI

I—Stretching and flexibility exercises

C—Are stretching and flexibility exercises equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

64.

P—Workers and/or patients with TBI

I—Relaxation exercises and group discussion

C—Are relaxation exercises and group discussion equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

65.

P—Workers and/or patients with TBI

I—Aerobic exercises

C—Are aerobic exercises equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

66.

P—Workers and/or patients with TBI

I—Aquatic therapy

C—Is aquatic therapy equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

67.

P—Workers and/or patients with TBI

I—Computer and video games

C—Are computer and video games equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

68.

P—Workers and/or patients with TBI

I—Virtual reality

C—Is virtual reality equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

69.

P—Workers and/or patients with TBI

I—Compensatory skills training

C—Is compensatory skills training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

70.

P—Workers and/or patients with TBI

I—Restorative and compensatory computer assisted cognitive remediation (CACR) and external aids

C—Are CACR and external aids equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

71.

P—Workers and/or patients with TBI

I—Attention process training (APT)

C—Is APT equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

72.

P—Workers and/or patients with TBI

I—Recreational computing

C—Is recreational computing equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

73.

P—Workers and/or patients with TBI

I—Computerized attention training with visual, auditory and divided training

C—Is computerized attention training with visual, auditory and divided training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

74.

P—Workers and/or patients with TBI

I—Captain's Log

C—Is Captain's Log equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

75.

P—Workers and/or patients with TBI

I—Restorative computer and non-computer attention remediation

C—Are restorative computer and non-computer attention remediation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

76.

P—Workers and/or patients with TBI

I—Reaction time training

C—Is reaction time training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

77.

P—Workers and/or patients with TBI

I—Perceptual skills training

C—Is perceptual skills training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

78.

P—Workers and/or patients with TBI

I—Verbal labeling training and compensatory interpersonal process recall

C—Are verbal labeling training and compensatory interpersonal process recall equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

79.

P—Workers and/or patients with TBI

I—Psychological functioning and activities of daily living (ADLs)

C—Are psychological functioning and ADLs equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

80.

P—Workers and/or patients with TBI

I—Memory/reasoning tasks, games and computer games

C— Memory/reasoning tasks, games and computer games equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

81.

P—Workers and/or patients with TBI

I—Computer memory retraining group (CMRG)

C—Is CMRG equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

82.

P—Workers and/or patients with TBI

I—Restorative imagery training

C—Is restorative imagery training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

83.

P—Workers and/or patients with TBI

I—Restorative functional skills training

C—Is restorative functional skills training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

84.

P—Workers and/or patients with TBI

I—Games, art, and other types of self-expression

C—Are games, art, and other types of self-expression equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

85.

P—Workers and/or patients with TBI

I—Computer-assisted cognitive rehabilitation

C—Is computer-assisted cognitive rehabilitation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

86.

P—Workers and/or patients with TBI

I—Induced hypothermia

C—Is induced hypothermia equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

87.

P—Workers and/or patients with TBI

I—Intracranial pressure monitoring and thresholds

C—Are intracranial pressure monitoring and thresholds equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

88.

P—Workers and/or patients with TBI

I—Oxygen monitoring and thresholds

C—Are oxygen monitoring and thresholds equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

89.

P—Workers and/or patients with TBI

I—Return to work

C—Is Return to work equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

90.

P—Workers and/or patients with TBI

I—Vocational rehabilitation programs

C—Are vocational rehabilitation programs equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

91.

P—Workers and/or patients with TBI

I—Functional capacity evaluations (FCEs)

C—Are FCEs equivalent or superior to other TBI assessment tools?

O—Treatment of TBI and/or symptoms

92.

P—Workers and/or patients with TBI

I—FCEs for chronic disabling cervical or thoracic pain

C—Are FCEs recommended assessments for chronic disabling cervical or thoracic pain?

O—Treatment of TBI and/or symptoms

93.

P—Workers and/or patients with TBI

I—FCEs for chronic stable cervicothoracic pain or post-operative recovery

C—Are FCEs recommended for assessment of chronic stable cervicothoracic pain or post-operative recovery?

O—Treatment of TBI and/or symptoms

94.

P—Workers and/or patients with TBI

I—FCEs for acute cervicothoracic pain, acute or subacute radicular syndromes, or post-surgical cervical or thoracic pain

C—Are FCEs recommended for acute cervicothoracic pain, acute or subacute radicular syndromes, or post-surgical cervical or thoracic pain?

O—Treatment of TBI and/or symptoms

95.

P—Workers and/or patients with TBI

I—Proton pump inhibitors (PPIs)

C—Are PPIs equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

96.

P—Workers and/or patients with TBI

I—Sucralfate

C—Is sucralfate equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

97.

P—Workers and/or patients with TBI

I—H2 blockers

C—Are H2 blockers equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

98.

P—Workers and/or patients with TBI

I—Nonsteroidal anti-inflammatory agents (NSAIDS)

C—Are NSAIDS equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

99.

P—Workers and/or patients with TBI

I—NSAIDs for febrile control

C—Are NSAIDs for febrile control equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

100.

P—Workers and/or patients with TBI

I—*Boswellia Serrata*

C—Is *Boswellia Serrata* equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

101.

P—Workers and/or patients with TBI

I—Other alternative, complementary, or homeopathic treatments

C—Are other alternative, complementary, or homeopathic treatments equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

102.

P—Workers and/or patients with TBI

I—Magnesium

C—Is magnesium equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

103.

P—Workers and/or patients with TBI

I—Progesterone

C—Is progesterone equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

104.

P—Workers and/or patients with TBI

I—Bromocriptine

C—Is bromocriptine equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

105.

P—Workers and/or patients with TBI

I—Cyclosporine

C—Is cyclosporine equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

106.

P—Workers and/or patients with TBI

I—Donepezil

C—Is donepezil equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

107.

P—Workers and/or patients with TBI

I—Mannitol for intracranial pressure

C—Is Mannitol for intracranial pressure equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

108.

P—Workers and/or patients with TBI

I—Hypertonic saline for intracranial pressure

C—Is hypertonic saline for intracranial pressure equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

109.

P—Workers and/or patients with TBI

I—Ringers lactate for intracranial pressure

C—Is Ringers lactate for intracranial pressure equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

110.

P—Workers and/or patients with TBI

I—Methylphenidate

C—Is methylphenidate equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

111.

P—Workers and/or patients with TBI

I—Modafinil

C—Is modafinil equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

112.

P—Workers and/or patients with TBI

I—Anti-spasticity medications

C—Are anti-spasticity medications equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

113.

P—Workers and/or patients with TBI

I—Antiseizure prophylaxis (anticonvulsants)

C—Is antiseizure prophylaxis (anticonvulsants) equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

114.

P—Workers and/or patients with TBI

I—Antidepressants

C—Are antidepressants equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

115.

P—Workers and/or patients with TBI

I—Benzodiazepines

C—Are benzodiazepines equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

116.

P—Workers and/or patients with TBI

I—Corticosteroids

C—Are corticosteroids equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

117.

P—Workers and/or patients with TBI

I—Excitatory amino acid inhibitors

C—Are excitatory amino acid inhibitors equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

118.

P—Workers and/or patients with TBI

I—Amantadine

C—Is amantadine equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

119.

P—Workers and/or patients with TBI

I—Cannabinoids

C—Are cannabinoids equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

120.

P—Workers and/or patients with TBI

I—Cerebrolysin

C—Is cerebrolysin equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

121.

P—Workers and/or patients with TBI

I—Tranexamic acid

C—Is tranexamic acid equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

122.

P—Workers and/or patients with TBI

I—Sedatives, sedative hypnotics, and opioids

C—Are sedatives, sedative hypnotics, and opioids equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

123.

P—Workers and/or patients with TBI

I—Barbiturates

C—Are barbiturates equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

124.

P—Workers and/or patients with TBI

I—Beta blockers

C—Are beta blockers equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

125.

P—Workers and/or patients with TBI

I—Aminosteroids

C—Are aminosteroids equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

126.

P—Workers and/or patients with TBI

I—Citicoline

C—Is citicoline equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

127.

P—Workers and/or patients with TBI

I—Physostigmine (eserine)

C—Is physostigmine (eserine) equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

128.

P—Workers and/or patients with TBI

I—Rivastigmine

C—Is rivastigmine equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

129.

P—Workers and/or patients with TBI

I—Cabergoline

C—Is cabergoline equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

130.

P—Workers and/or patients with TBI

I—Deamino arginine vasopressin (DDAVP)

C—Is deamino arginine vasopressin (DDAVP) equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

131.

P—Workers and/or patients with TBI

I—Memantine

C—Is memantine equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

132.

P—Workers and/or patients with TBI

I—Substance P antagonists

C—Are substance P Antagonists equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

133.

P—Workers and/or patients with TBI

I—Piracetam

C—Is piracetam equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

134.

P—Workers and/or patients with TBI

I—Intrathecal baclofen pumps

C—Are intrathecal baclofen pumps equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

135.

P—Workers and/or patients with TBI

I—Nutritional support

C—Is Nutritional support equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

136.

P—Workers and/or patients with TBI

I—Rest

C—Is rest equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

137.

P—Workers and/or patients with TBI

I—Body weight support treadmill

C—Is a body weight support treadmill equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

138.

P—Workers and/or patients with TBI

I—Constraint-induced movement therapy

C—Is constraint-induced movement therapy equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

139.

P—Workers and/or patients with TBI

I—Whole body vibration (WBV)

C—Is WBV equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

140.

P—Workers and/or patients with TBI

I—Cognitive behavioral therapy (CBT)

C—Is CBT equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

141.

P—Workers and/or patients with TBI

I—Education programs

C—Are education programs equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

142.

P—Workers and/or patients with TBI

I—Neuroplasticity

C—Is neuroplasticity equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

143.

P—Workers and/or patients with TBI

I—Robotics

C—Are robotics equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

144.

P—Workers and/or patients with TBI

I—Vestibular rehabilitation treatment

C—Is vestibular rehabilitation treatment equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

145.

P—Workers and/or patients with TBI

I—Radiofrequency neurotomy, neurotomy, and facet rhizotomy

C—Are radiofrequency neurotomy, neurotomy, and facet rhizotomy equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

146.

P—Workers and/or patients with TBI

I—Radiofrequency neurotomy for cervicogenic headache

C—Is radiofrequency for cervicogenic headache equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

147.

P—Workers and/or patients with TBI

I—Occipital nerve blocks

C—Are occipital nerve blocks equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

148.

P—Workers and/or patients with TBI

I—Non-invasive occipital nerve stimulation (ONS)

C—Is ONS equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

149.

P—Workers and/or patients with TBI

I—Implantable occipital nerve stimulation devices

C—Are implantable ONS devices equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

150.

P—Workers and/or patients with TBI

I—Botulinum toxin

C—Is botulinum toxin equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

151.

P—Workers and/or patients with TBI

I—Meniett device

C—Is the Meniett device equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

152.

P—Workers and/or patients with TBI

I—Transcranial magnetic stimulation (TMS)

C—Is TMS equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

153.

P—Workers and/or patients with TBI

I—Transcranial direct current stimulation (TDCS)

C—Is TDCS equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

154.

P—Workers and/or patients with TBI

I—Hyperbaric oxygen therapy (HBO or HBOT)

C—Is HBO or HBOT equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

155.

P—Workers and/or patients with TBI

I—Manipulation / mobilization for cervicothoracic pain

C—Is manipulation / mobilization for cervicothoracic pain equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

156.

P—Workers and/or patients with TBI

I—Manipulation for chronic cervicogenic headache pain

C—Is manipulation for chronic cervicogenic headache pain equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

157.

P—Workers and/or patients with TBI

I—Manipulation of cervical spine

C—Is manipulation of cervical spine equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

158.

P—Workers and/or patients with TBI

I—Cervical manipulation for tension headaches

C—Is cervical manipulation for tension headaches equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

159.

P—Workers and/or patients with TBI

I—Routine manipulation / mobilization

C—Is routine manipulation / mobilization equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

160.

P—Workers and/or patients with TBI

I—Manipulation for radicular pain syndromes with acute neurological deficits

C—Is manipulation for radicular pain syndromes with acute neurological deficits equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

161.

P—Workers and/or patients with TBI

I—Manipulation for radicular pain without neurological deficits

C—Is manipulation for radicular pain without neurological deficits equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

162.

P—Workers and/or patients with TBI

I—Deep thalamic simulation

C—Is deep thalamic stimulation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

163.

P—Workers and/or patients with TBI

I—Acupuncture for cervicothoracic pain

C—Is acupuncture for cervicothoracic pain equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

164.

P—Workers and/or patients with TBI

I—Induced hypothermia

C—Is induced hypothermia equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

165.

P—Workers and/or patients with TBI

I—Laser therapy/low-level laser therapy

C—Is laser therapy or low-level laser therapy equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

166.

P—Workers and/or patients with TBI

I—Functional electrical stimulation (FES)

C—Is FES equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

167.

P—Workers and/or patients with TBI

I—Neuromuscular electrical stimulation (NMES)

C—Is NMES equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

168.

P—Workers and/or patients with TBI

I—Hyperventilation

C—Is hyperventilation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

169.

P—Workers and/or patients with TBI

I—Behavioral programs

C—Are behavioral programs equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

170.

P—Workers and/or patients with TBI

I—Outpatient home and community-based rehabilitation

C—Is outpatient home and community-based rehabilitation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

171.

P—Workers and/or patients with TBI

I—Comprehensive integrated interdisciplinary rehabilitation

C—Is comprehensive integrated interdisciplinary rehabilitation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

172.

P—Workers and/or patients with TBI

I—Residential rehabilitation

C—Is residential rehabilitation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

173.

P—Workers and/or patients with TBI

I—Supported living programs

C—Are supported living programs equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

174.

P—Workers and/or patients with TBI

I—Skilled nursing facilities (SNFs)

C—Are SNFs equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

175.

P—Workers and/or patients with TBI

I—Occupational rehabilitation

C—Is occupational rehabilitation equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

176.

P—Workers and/or patients with TBI

I—Opioid/chemical treatment programs

C—Are opioid/chemical treatment programs equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

177.

P—Workers and/or patients with TBI

I—Music therapy

C—Is music therapy equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

178.

P—Workers and/or patients with TBI

I—Ankle-foot orthotics

C—Are ankle-foot orthotics equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

179.

P—Workers and/or patients with TBI

I—Adaptive devices, casting, and orthotics

C—Are adaptive devices, casting and orthotics equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

180.

P—Workers and/or patients with TBI

I—Neuromuscular re-education

C—Is neuromuscular re-education equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

181.

P—Workers and/or patients with TBI

I—Muscle tone and joint restriction management

C—Is muscle tone and joint restriction management equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

182.

P—Workers and/or patients with TBI

I—Mood stabilizers

C—Are mood stabilizers equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

183.

P—Workers and/or patients with TBI

I—Attention regulation training

C—Is attention regulation training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

184.

P—Workers and/or patients with TBI

I—Anger management training

C—Is anger management training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

185.

P—Workers and/or patients with TBI

I—Suicide prevention

C—Is suicide prevention equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

186.

P—Workers and/or patients with TBI

I—Motivational interviewing

C—Is motivational interviewing equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

187.

P—Workers and/or patients with TBI

I—Emotional training

C—Is emotional training equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

188.

P—Workers and/or patients with TBI

I—Goal setting

C—Is goal setting equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

189.

P—Workers and/or patients with TBI

I—Peer monitoring program

C—Is a peer monitoring program equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

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Traumatic Brain Injury: Tables

Table 1. Glasgow Coma Scale

Response	Scale	Score
Eye Opening Response	Eyes open spontaneously	4 Points
	Eyes open to verbal command, speech or shout	3 Points
	Eyes open to pain (not applied to face)	2 Points
	No eye opening	1 Point
Verbal Response	Oriented	5 Points
	Confused conversation but able to answer questions	4 Points
	Inappropriate responses but words discernable	3 Points
	Incomprehensible sounds or speech	2 Points
	No verbal response	1 Point
Motor Response	Obeys commands for movement	6 Points
	Purposeful movement to painful stimulus	5 Points
	Withdraws from pain	4 Points
	Abnormal (spastic) flexion, decorticate posture	3 Points
	Extensor (rigid) response, decerebrate posture	2 Points
	No motor responses	1 Points

Adapted from Teasdale G, Jennett B. Assessment of coma and impaired consciousness. Lancet 1974; 81-84.

Table 2. Red Flags for Potentially Serious TBI (including Neck/Thoracic Spine Conditions)

Disorder	Medical History	Physical Examination/Diagnostic Testing
Increased intracranial pressure	Altered consciousness, coma Headache History of hypertension Organ-system relevant history features if history of focal intracranial damage or bleeding	Altered mental status Altered consciousness Concurrent elevated blood pressure Papilledema, CN VI abnormalities, Cushing's triad, blurred vision, unreactive pupils, abnormal posturing.
Intracerebral hemorrhages	Headache Nausea and vomiting Organ-system relevant history features if history of focal intracranial damage or bleeding	Altered consciousness Organ-system relevant physical examination features if history of focal intracranial damage or bleeding
Central nervous system impairments	Abnormal balance Loss of consciousness Nausea Visual difficulties Organ-system relevant history features if history of focal intracranial damage or bleeding	Vertigo lasting for more than seconds Vestibular dysfunction Hearing loss (unilateral) Visual dysfunction Organ-system relevant physical examination features if history of focal intracranial damage or bleeding
Fracture	Major trauma, such as vehicular accident or fall from height [(956)] Minor trauma or strenuous lifting in older or potentially osteoporotic patients Metabolic risks for osteopenia (including renal failure, hyperthyroidism, rheumatic disorders, debility and inheritance)	Percussion tenderness over specific spinous processes Careful neurological examination for signs of neurological compromise
Substance abuse with risk of withdrawal	Substance(s) abuse Prior substance(s) withdrawal	Dilated pupils Tachycardia Sweating
Progressive neurologic deficit	Progressive limb numbness or weakness, bowel or bladder control impairment, gait ataxia Progressive loss in any sensory function (e.g., vision, hearing, balance, sensation) Severe spine pain	Progressive loss in any sensory function (e.g., visual acuity/Snellen, visual fields, audiometry, Romberg, balance, sensation) Significant and progressive myotomal motor weakness Significant and increased sensory loss – in anatomical distribution

		Radicular signs Corticospinal tract involvement (gait ataxia, Babinski sign, hyperreflexia, and limb spasticity, etc.) Other neurological impairment(s)
Myelopathy	Ataxic gait, impaired upper limb coordination, poor or reduced finger movements, bladder and/or bowel control impairment (incontinence)	Hyperreflexia, ataxia, clonus, pathologic reflexes (Babinski, Hoffman) Other neurological impairment(s)

Absent red flags, TBI can be classified into one of three working categories described in Classification**.**

Table 3. Physical Examination Correlates of Cervical Nerve Root Dysfunction

Root Level	Sensory Deficit	Motor Weakness	Reflex
C3	Ear, anterior neck, occiput, posterior temporal area	Not usually detectable	None
C4	Shoulder, posterior upper arm, upper chest	Not usually detectable	None
C5	Lateral shoulder, upper arm	Shoulder abduction, elbow flexion	Biceps
C6	Lateral forearm, **thumb*** and perhaps index finger	wrist extension (ECRL/ECRB) and elbow flexion (biceps)	Brachioradialis, and possibly biceps
C7	**Middle** finger*	Elbow extension (triceps), wrist flexion, finger extension	Triceps
C8	Distal forearm, ulnar ring, and **little*** finger	Finger flexion	Triceps
T1	Medial upper forearm and arm	middle finger flexion, finger abduction and adduction	None
T2-T12	Unilateral, dermatomal based on nerve root(s) affected	Generally none unless multiple roots affected	None

**These are the most common sensory nerve deficits related to cervical nerve root dysfunction.*