AMERICAN COLLEGE OF OCCUPATIONAL AND ENVIRONMENTAL MEDICINE

Traumatic Brain Injury

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Summary of Recommendations

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 was unavailable or inconsistent (see Methodology). The reader is cautioned to utilize the more detailed indications, specific appropriate diagnoses, temporal sequencing, preceding testing or conservative treatment, and contraindications that are elaborated in more detail for each test or treatment in the body of this Guideline in 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

Test/Procedure/Treatment	Details	Recommendation
Acupuncture	Acupuncture for Acute or Subacute Cervicothoracic Pain	Not Recommended, Insufficient Evidence (I)
	Acupuncture for Chronic Cervicothoracic Pain	Recommended, Evidence (C)
Allied Health	Meniett Device	Recommended, Insufficient Evidence (I)
	Transcranial Direct Current Stimulation	No Recommendation, Insufficient Evidence (I)
	Transcranial Magnetic Stimulation	No Recommendation, Insufficient Evidence (I)
Attention Tests / Training	"Captain's Log"- Computer Training Program for Attention Skills with Tasks for Vigilance, Inattention, Prudence, Impulsivity, Focus, Variability, and Speed	No Recommendation, Insufficient Evidence (I)
	Attention Process Training	Recommended, Insufficient Evidence (I)
	Attention Regulation Training	Recommended, Evidence (C)
	Attention Tests	Recommended, Insufficient Evidence (I)
	Computerized Attention Training with Visual, Auditory, and Divided Training	Recommended, Insufficient Evidence (I)
	Reaction Time Training	No Recommendation, Insufficient Evidence (I)
	Recreational Computing	Recommended, Insufficient Evidence (I)
	Restorative Computer and Non-Computer Attention Remediation	No Recommendation, Insufficient Evidence (I)
Audiological Tests	Audiometry	Recommended, Insufficient Evidence (I)
	Brainstem Auditory Evoked Response	Recommended, Insufficient Evidence (I)
	Tympanometry	No Recommendation, Insufficient Evidence (I)
Balance Tests / Training	Computerized Dynamic Platform Posturography	No Recommendation, Insufficient Evidence (I)
	Computer & Video Games for Balance	Recommended, Insufficient Evidence (I)

Test/Procedure/Treatment	Details	Recommendation
	Electro- or Video Nystagmography	No Recommendation, Insufficient Evidence (I)
	Electronystagmogram Studies	Recommended, Insufficient Evidence (I)
	Rotary Chair Testing	Recommended, Insufficient Evidence (I)
	Vestibular Rehabilitation	Recommended, Evidence (C)
	Virtual Reality for Balance	Recommended, Evidence (C)
Behavioral / Psych	Anger Management Therapy	Recommended, Insufficient Evidence (I)
	Behavioral Programs	Recommended, Insufficient Evidence (I)
	Cognitive Behavioral Therapies	Recommended, Evidence (C)
	Community-Based Life Goals	No Recommendation, Insufficient Evidence (I)
	Emotional Training	Recommended, Insufficient Evidence (I)
	Goal Setting	Recommended, Insufficient Evidence (I)
	Motivational Interviewing	Recommended, Insufficient Evidence (I)
	Peer-Mentoring Program	No Recommendation, Insufficient Evidence (I)
	Psychosocial Functioning and ADLs	Recommended, Insufficient Evidence (I)
	Substance Abuse Counseling	Recommended, Insufficient Evidence (I)
	Suicide Prevention	Recommended, Evidence (C)
	Video Feedback on Task Performance	Recommended, Insufficient Evidence (I)
Biofeedback	Biofeedback for TBI Patients	No Recommendation, Insufficient Evidence (I)
Biomarkers	Biomarkers	No Recommendation, Insufficient Evidence (I)
Botox	Botulinum Toxin	Recommended, Evidence (C)
Debridement	Debridement	See Guideline
Decompression	Decompression and Facial Nerve Decompression	See Guideline
Education	Education Program	Recommended, Insufficient Evidence (I)
EEG	Electroencephalography	Recommended, Insufficient Evidence (I)
	Quantitative Electroencephalograph	No Recommendation, Insufficient Evidence (I)
Electrical Stimulation	Functional Electrical Stimulation	No Recommendation, Insufficient Evidence (I)
	Neuromuscular Electrical Stimulation	No Recommendation, Insufficient Evidence (I)
Electrodiagnostics	Electromyelography and Nerve Conduction Studies	Recommended, Insufficient Evidence (I)
	Electroneuronography	Recommended, Insufficient Evidence (I)
Evoked Potentials	Somatosensory Evoked Potentials	Recommended, Insufficient Evidence (I)
	Vestibular Evoked Myogenic Potentials	No Recommendation, Insufficient Evidence (I)
Executive Function	Executive Function Tests	Recommended, Insufficient Evidence (I)
Exercise	Aerobic Exercise	Recommended, Insufficient Evidence (I)
	Aquatic Therapy	Recommended, Evidence (C)
	Strengthening Exercises	Recommended, Insufficient Evidence (I)
	Stretching and Flexibility Exercises	Recommended, Insufficient Evidence (I)
Family Visits	Family Visits	Recommended, Evidence (C)
Functional Capacity Evaluations	FCEs for Acute Cervicothoracic Pain, Acute or Subacute Radicular Syndromes, or Post-Surgical Cervical or Thoracic Pain	Not Recommended, Insufficient Evidence (I)

Test/Procedure/Treatment	Details	Recommendation
	FCEs for Chronic Disabling Cervical or Thoracic Pain	Recommended, Insufficient Evidence (I)
	FCEs for Chronic Stable Cervicothoracic Pain or Post-operative Recovery	No Recommendation, Insufficient Evidence (I)
	FCEs for TBI Patients	Recommended, Insufficient Evidence (I)
Group Discussions	Group Discussions	No Recommendation, Insufficient Evidence (I)
Hyperbaric Oxygen	Hyperbaric Oxygen Therapy	Mild: Moderately Not Recommended; Moderate: No Recommendation; Severe: Moderately Recommended
Hyperventilation	Hyperventilation	Recommended, Insufficient Evidence (I)
Hypothermia	Induced Hypothermia	Not Recommended, Evidence (C)
Imaging	Brain Acoustic Monitor	No Recommendation, Insufficient Evidence (I)
	Computed Tomography	Recommended, Evidence (C)
	Diffusion Tensor Imaging	Recommended, Evidence (C)
	Functional Magnetic Resonance Imaging	No Recommendation, Insufficient Evidence (I)
	Magnetic Resonance Imaging	Moderately Recommended, Evidence (B)
	Magnetic Resonance Spectroscopy	No Recommendation, Insufficient Evidence (I)
	Positron Emission Test	No Recommendation, Insufficient Evidence (I)
	Single-Photon Emission Computerized Tomography	No Recommendation, Insufficient Evidence (I)
	Skull X-Rays	Recommended, Insufficient Evidence (I)
	Ultrasonography	Recommended, Insufficient Evidence (I)
	Vascular Imaging Tests	Recommended, Insufficient Evidence (I)
Intelligence Tests	Automated Neuropsychological Assessment Metrics [1]	Moderately Recommended, Evidence (B)
	Wechsler Adult Intelligence Scale (WAIS, WAIS-III))	Moderately Recommended, Evidence (B)
Intracranial Pressure	Intracranial Pressure Monitoring and Thresholds	Recommended, Evidence (C)
Lab Tests	Laboratory Testing	See Guideline
Laser Therapy	Laser Therapy/Low-Level Laser Therapy	No Recommendation, Insufficient Evidence (I)
Lumbar Puncture	Lumbar Puncture	See Guideline
Manipulation / Mobilization	Cervical Manipulation for Tension Headaches	Not Recommended, Evidence (C)
	Deep Thalamic Stimulation	No Recommendation, Insufficient Evidence (I)
	Manipulation for Cervical Spine Conditions	Not Recommended, Insufficient Evidence (I)
	Manipulation for Chronic Cervicogenic Headache Pain	Recommended, Evidence (C)
	Manipulation for Radicular Pain Syndromes with Acute Neurological Deficits	Not Recommended, Insufficient Evidence (I)
	Manipulation for Radicular Pain Syndromes without Neurologic Deficits	No Recommendation, Insufficient Evidence (I)
	Manipulation/Mobilization for Acute, Subacute, or Chronic Cervicothoracic Pain	Recommended, Insufficient Evidence (I)
	Regular or Routine Manipulation or Mobilization	Not Recommended, Insufficient Evidence (I)

Test/Procedure/Treatment	Details	Recommendation
Medications	Amantadine for Mild TBI Patients, Pre/Peri/Post-Operative	No Recommendation, Insufficient Evidence (I)
	Amantadine for Subacute, Moderate TBI Patients	Recommended, Insufficient Evidence (I)
	Amantadine for Subacute, Severe TBI Patients	Moderately Recommended, Evidence (B)
	Aminosteroids for TBI Patients	Not Recommended, Insufficient Evidence (I)
	Antidepressants for TBI Patients	Recommended, Insufficient Evidence (I)
	Antiseizure Prophylaxis (Anticonvulsants) for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Anti-spasticity Medications for TBI Patients	Recommended, Evidence (C)
	Atypical Antipsychotics for TBI Patients	Recommended, Insufficient Evidence (I)
	Barbiturates for TBI Patients	Not Recommended, Evidence (C)
	Benzodiazepines for TBI, Most Patients	Not Recommended, Insufficient Evidence (I)
	Benzodiazepines for TBI, Select Patients	Recommended, Insufficient Evidence (I)
	Beta Blockers for TBI Patients	Recommended, Evidence (C)
	Boswellia Serrata for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Bromocriptine for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Cabergoline for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Cannabinoids for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Cerebrolysin for TBI Patients (not currently approved for use in U.S.)	No Recommendation, Insufficient Evidence (I)
	Citicoline for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Corticosteroids for TBI Patients	Moderately Not Recommended, Evidence (B)
	Cyclosporine for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Deamino Arginine Vasopressin (DDAVP) for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Dextromethorphan for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Donepezil for TBI Patients	Recommended, Insufficient Evidence (I)
	Excitatory Amino Acid Inhibitors for TBI Patients	No Recommendation, Insufficient Evidence (I)
	H2 Blockers	Recommended, Evidence (C)
	Magnesium for TBI Patients	Not Recommended, Insufficient Evidence (I)
	Memantine for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Methylphenidate for TBI Patients	Recommended, Insufficient Evidence (I)
	Modafinil for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Mood Stabilizers for TBI Patients	No Recommendation, Insufficient Evidence (I)
	NSAIDs for Febrile Control	Recommended, Insufficient Evidence (I)
	NSAIDs for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Other Alternative, Complementary, Homeopathic Treatments for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Physostigmine (Eserine) for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Piracetam for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Progesterone for TBI Patients	Not Recommended, Insufficient Evidence (I)

Test/Procedure/Treatment	Details	Recommendation
	Proton Pump Inhibitors (PPIs)	Strongly Recommended, Evidence (A)
	Rivastigmine for TBI Patients	Recommended, Insufficient Evidence (I)
	Sedatives, Sedative Hypnotics, and Opioids for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Substance P Antagonists for TBI Patients	No Recommendation, Insufficient Evidence (I)
	Sucralfate	Moderately Recommended, Evidence (B)
	Tranexamic Acid for TBI Patients	Recommended, Evidence (C)
	Triptans and Ergot Alkaloids for Post-TBI Migraine Headaches	Recommended, Insufficient Evidence (I)
Memory / Malingering Tests	California Verbal Learning Test (CVLT-I and CVLT-II)	Recommended, Insufficient Evidence (I)
	Cognitive Event Related Potential	Recommended, Evidence (C)
	Memory and Malingering Tests	Recommended, Insufficient Evidence (I)
	Repeatable Battery of the Assessment of Neuropsychological Status (RBANS	Recommended, Insufficient Evidence (I)
	Test of Memory Malingering	Moderately Recommended, Evidence (B)
	Wechsler Memory Scale III (WMS-III)	Moderately Recommended, Evidence (B)
Memory / Motor Imagery	Computer Memory Retraining Group	Recommended, Evidence (C)
	Handheld Computers as Memory Aids	Moderately Recommended, Evidence (B)
	Memory Rehabilitation	Recommended, Insufficient Evidence (I)
	Memory/Reasoning Tasks, Games, Computer Games	Recommended, Insufficient Evidence (I)
	Restorative Functional Skills Training	No Recommendation, Insufficient Evidence (I)
	Restorative Imagery Training	Moderately Recommended, Evidence (B)
Nerve Blocks	Occipital Nerve Blocks for Cervicogenic Headache	Recommended, Evidence (C)
	Occipital Nerve Blocks for Migraine Headache	No Recommendation, Insufficient Evidence (I)
	Radiofrequency Neurotomy for Cervicogenic Headache	Moderately Not Recommended, Evidence (B)
	Radiofrequency Neurotomy, Neurotomy, or Facet Rhizotomy for Chronic Cervicothoracic Pain	No Recommendation, Insufficient Evidence (I)
Nerve Stimulation	Implantable Occipital Nerve Stimulation Devices	Not Recommended, Insufficient Evidence (I)
	Non-Invasive Occipital and Supraorbital Nerve Stimulation	Recommended, Evidence (C)
Neuropsych Tests	Neurocognitive Testing	Recommended, Insufficient Evidence (I)
	Neuropsychological Assessment	Recommended, Insufficient Evidence (I)
Nutritional Support	Nutritional Support in TBI Patients	Recommended, Evidence (C)
Orthotics	Adaptive Devices, Casting and Orthotics	Recommended, Insufficient Evidence (I)
	Ankle-foot Orthotics for Treatment of Foot Drop	Recommended, Insufficient Evidence (I)
Osmotherapy	Hypertonic Saline for Intracranial Pressure	Recommended, Insufficient Evidence (I)
	Mannitol for Intracranial Pressure	Recommended, Insufficient Evidence (I)
	Ringers Lactate for Intracranial Pressure	No Recommendation, Insufficient Evidence (I)
OT / PT	Action Sequences	Recommended, Insufficient Evidence (I)

Test/Procedure/Treatment	Details	Recommendation
	Body Weight Support Treadmill Training for TBI Patients	Recommended, Insufficient Evidence (I)
	Cognitive-Motor Dual-Tasking	Recommended, Insufficient Evidence (I)
	Constraint-Induced Movement Therapy (CI) for TBI Patients	Recommended, Evidence (C)
	Neuroplasticity	No Recommendation, Insufficient Evidence (I)
	Occupational Rehabilitation	Recommended, Evidence (C)
	Occupational Therapy	Recommended, Insufficient Evidence (I)
	Physical Therapy	Recommended, Insufficient Evidence (I)
	Specific Motor Stimulation	Recommended, Insufficient Evidence (I)
	Systematic Instruction	Recommended, Evidence (C)
	Television Assisted Rehabilitation	Recommended, Evidence (C)
	Whole Body Vibration (WBV) for TBI Patients	No Recommendation, Insufficient Evidence (I)
Oxygen Monitoring	Oxygen Monitoring and Thresholds	Recommended, Evidence (C)
Pain Pumps	Inthrathecal Baclofen (ITB) Pump for TBI Patients	Recommended, Insufficient Evidence (I)
Perception	Perceptual Skills Training	No Recommendation, Insufficient Evidence (I)
	Verbal Labeling Training and Compensatory Interpersonal Process Recall	Recommended, Insufficient Evidence (I)
Personality Tests	Minnesota Multiphasic Personality Inventory (MMPI)	Recommended, Evidence (C)
Post-concussion	Immediate Post-Concussion Assessment and Cognitive Testing	Recommended, Insufficient Evidence (I)
	King-Devick	Recommended, Evidence (C)
	Military Acute Concussion Evaluation	No Recommendation, Insufficient Evidence (I)
	Sport Concussion Assessment Tool (SCAT)	Recommended, Insufficient Evidence (I)
Problem-Solving	Compensatory Skills Training	Recommended, Insufficient Evidence (I)
	Group Sessions for Problem Solving, Discussion of Social Isolations and Frustrations	Recommended, Evidence (C)
	Restorative and Compensatory Computer Assisted Cognitive Remediation (CACR) and External Aids	No Recommendation, Insufficient Evidence (I)
Rehab, General	Distance-based Healthcare (Telehealth; Telemedicine)	See Initial Approaches to Treatment Guideline
	Inpatient: Comprehensive Integrated Interdisciplinary Rehabilitation	Recommended, Insufficient Evidence (I)
	Outpatient: Home and Community-Based Rehabilitation	Recommended, Insufficient Evidence (I)
	Residential Rehabilitation	Recommended, Insufficient Evidence (I)
	Skilled Nursing Facilities	Recommended, Insufficient Evidence (I)
	Supported Living Programs	Recommended, Insufficient Evidence (I)
Rehab, Other	Computer-Assisted Cognitive Rehabilitation	Recommended, Evidence (C)
	Games, Art, and Self-Expression	Recommended, Insufficient Evidence (I)
	High-Order Reasoning Training	Recommended, Evidence (C)

Test/Procedure/Treatment	Details	Recommendation
	Muscle Tone and Joint Restriction Management	No Recommendation, Insufficient Evidence (I)
	Music Therapy	No Recommendation, Insufficient Evidence (I)
	Neuromuscular Re-Education	No Recommendation, Insufficient Evidence (I)
	Opioid/Chemical Treatment Programs	Recommended, Insufficient Evidence (I)
	Reading Comprehension Exercises	No Recommendation, Insufficient Evidence (I)
Relaxation	Relaxation Exercises	No Recommendation, Insufficient Evidence (I)
Rest	Rest	Not Recommended, Evidence (C)
Return to Work	Job Site Evaluations	See Guideline
	Return to Work	Recommended, Insufficient Evidence (I)
	Vocational Rehabilitation Programs	Recommended, Insufficient Evidence (I)
Robotics	Robotics	Recommended, Evidence (C)
Stimulation	Multimodal and Unimodal Coma Stimulation	Recommended, Evidence (C)
Surgery	Surgical Recommendations	See Guideline
Swallow Tests	Swallow Studies	See Guideline
Vestibular Function Tests	Vestibular Function Test	Recommended, Insufficient Evidence (I)
Vision Tests / Training	Electroretinogram (ERG)	No Recommendation, Insufficient Evidence (I)
	Fluorescein Angiography	Recommended, Insufficient Evidence (I)
	Oculomotor Training	Recommended, Insufficient Evidence (I)
	Optical Coherence Tomography	No Recommendation, Insufficient Evidence (I)
	Vision Training	Recommended, Insufficient Evidence (I)
	Visual Acuity Testing	Recommended, Insufficient Evidence (I)
	Visual Evoked Potentials (VEP)	Recommended, Insufficient Evidence (I)
	Visual Field Testing	Recommended, Insufficient Evidence (I)
	Visual Perceptual Testing	Recommended, Insufficient Evidence (I)

Overview

This clinical practice guideline presents 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.

This TBI treatment guideline provides evidence-based guidance 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 health care providers. 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.

The literature is routinely monitored and searched at least annually for evidence that would overturn the guidance. The guideline is planned to be comprehensively updated at least every five years, or more frequently should evidence require it. The health questions for acute, subacute, chronic, and post-operative 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?
- When and for what conditions is surgery recommended?
- What management options are recommended for delayed recovery?

A detailed list of search questions in a PICO-type format (Patient/Population, Intervention, Comparison, Outcome) is in Appendix 2. A detailed methodology document used for guideline development is available online as a full-length document [2] and has also been summarized elsewhere [3, 4]; the methodology document includes evidence selection, scoring, incorporation of cost considerations,[5, 6] and formulation of recommendations. All evidence garnered from 7 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 2016 to help assure complete capture. 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[5] and auditing/monitoring.[6] Alternative options to manage conditions are provided. It is recognized that there are differences in workers' compensation systems.[7] There also are regional differences in treatment approaches.[8-10]

This guideline has undergone extensive external peer review. All AGREE II [6, 11], IOM [5] [12], 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.[5]

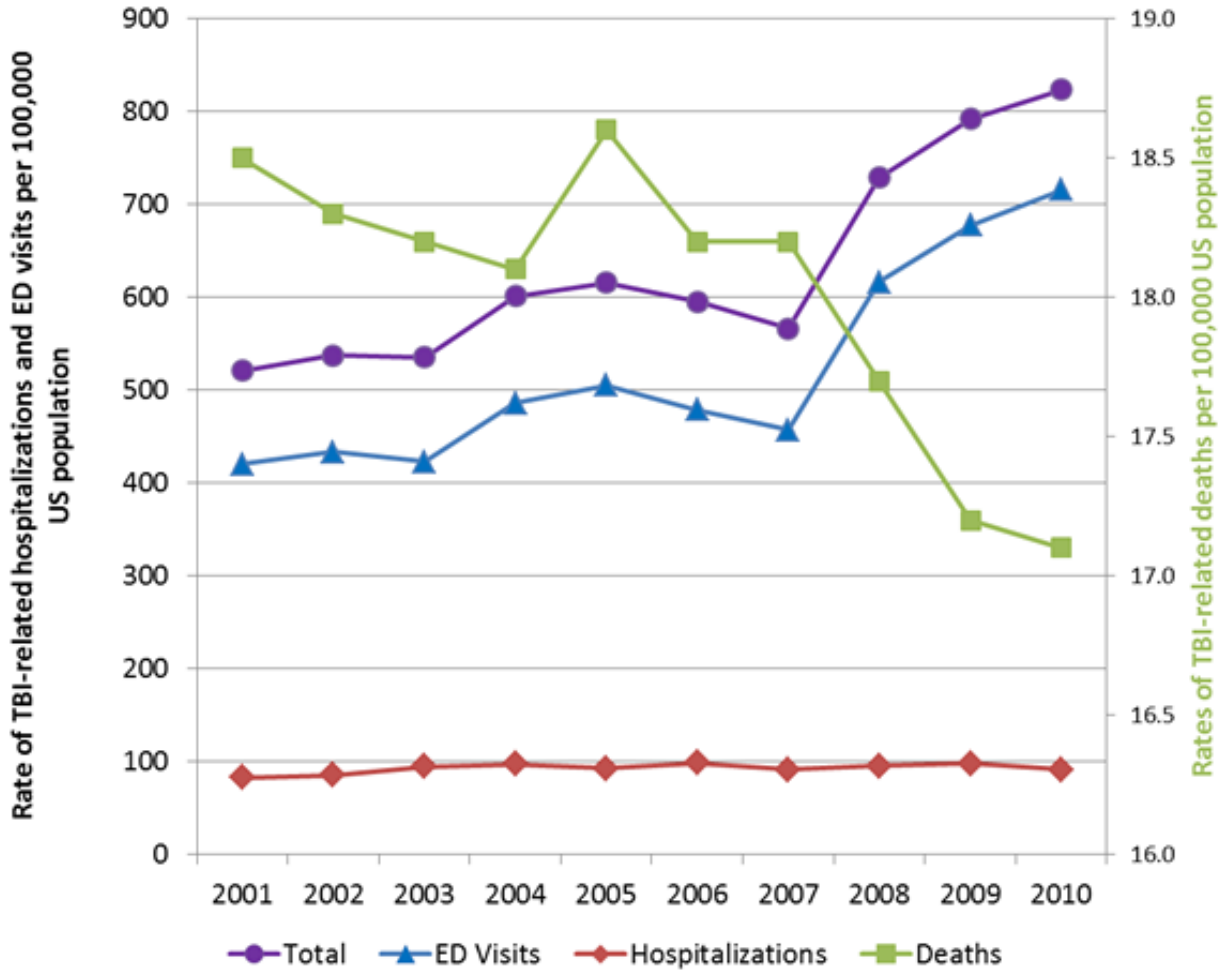
The Evidence-based Practice Traumatic Brain Injury Panel and the Research Team have complete editorial independence from the American College of Occupational and Environmental Medicine and Reed Group, which have not influenced the guidelines.

Impact

Traumatic brain injury (TBI) has been estimated to affect 1.7 to 10 million people annually in the general United States population [13-16]. The incidence of TBI has steadily risen from 2001 to 2010, as measured by combined emergency department (ED) visits, hospitalizations, and deaths. However, the rates of death from TBI have trended down modestly (see Figure 1, below). From 2001 to 2005, the TBI rate increased from 521 to 616 per 100,000; in 2010, it increased to 824 per 100,000 population [17]. TBI-related ED visits increased by 70% from 2001 to 2010, while hospitalization rates increased by only 11%. Additionally, deaths related to TBI decreased by 7% over the same 10-year span [17]. 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, while unable to prevent TBIs entirely, have somewhat mitigated the severity of TBI and thus mortality. Jager et al. reported a rate of 18/100,000

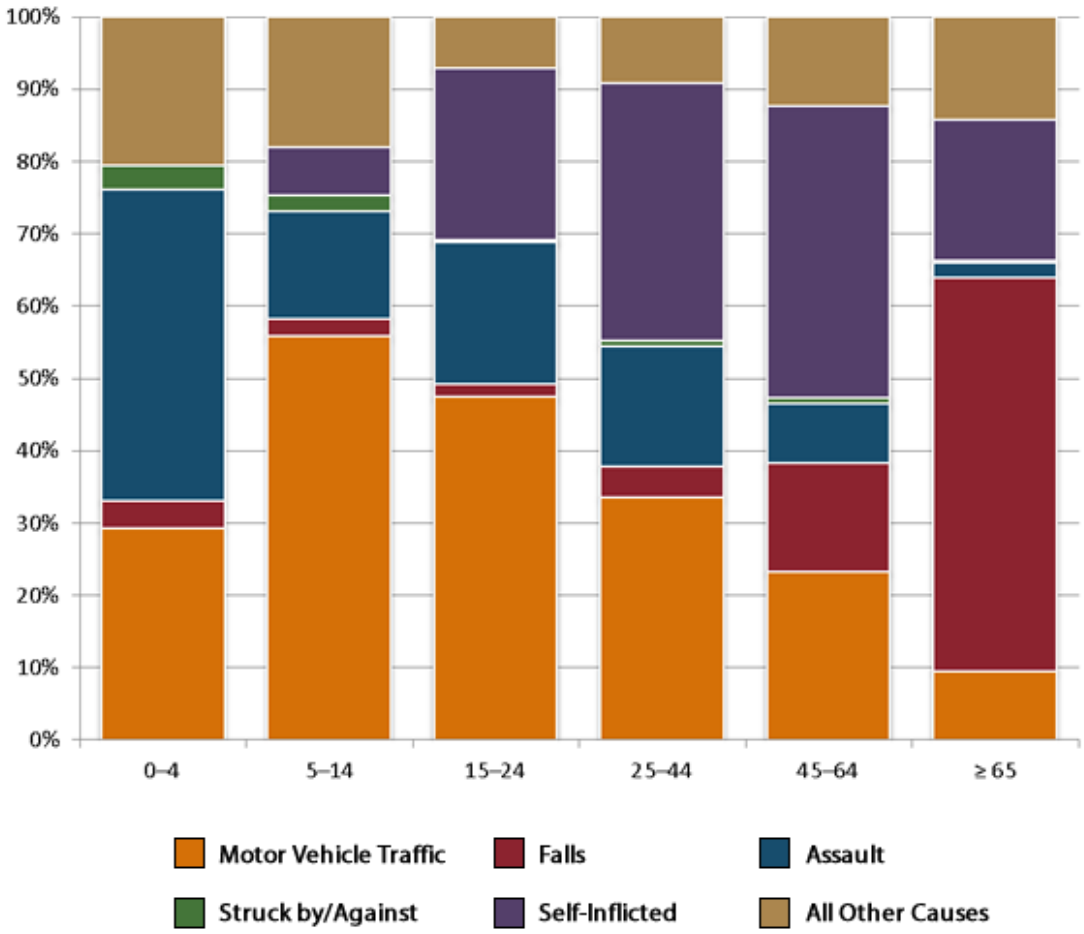
TBIs occurring in the workplace from 1992-1994 [18]. TBI may occur less frequently in the workplace compared to other injuries, but it carries enormous per capita costs, in large part due to vocational issues of impairments, employability, and productivity. It is estimated that the average lifetime cost of a TBI patient ranges from $600,000 to $1,875,000. [19]. 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 [20], with another estimate of more than 10 million affected individuals and approximately 50% on long-term disability [21]. These are likely underestimates of the prevalence of TBI because they do not include persons with TBI sequelae who were treated and released from EDs, those who sought care in other health-care settings, and those who did not seek treatment [22-24].

Figure 1. Rates of TBI-related Emergency Department Visits, Hospitalizations, and Deaths in the United States, 2001—2010



Adapted from the Centers for Disease Control and Prevention, *Rates of TBI-related Emergency Department Visits, Hospitalizations, and Deaths — United States, 2001–2010* (https://www.cdc.gov/traumaticbraininjury/data/rates.html).

Figure 2. Percent Distributions of TBI-related Deaths by Age Group and Injury Mechanism — United States, 2006–2010



Adapted from the Centers for Disease Control and Prevention, *Percent Distributions of TBI-related Deaths by Age Group and Injury Mechanism — United States, 2006–2010* (https://www.cdc.gov/traumaticbraininjury/data/dist_death.html).

Definitions and Related Terms

Active Therapy: The term "active therapy" is generally thought of as the patient taking an active role in the treatment of their disorder 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.[25] Therapeutic exercises could include light aerobic activity, directional exercises, muscle reconditioning (light-weight lifting or resistance training), physiotherapy, and active physical or occupational therapy.[26]

Acute, Subacute and Chronic: *Acute, subacute and chronic pain* are categorized as less than 1 month, 1 to 3 months, and greater than 3 months duration respectively. *Acute, subacute and chronic TBI* are categorized as less than 1 month, 1 to 3 months, and greater than 3 months duration respectively.

Chronic Traumatic Encephalopathy: Chronic Traumatic Encephalopathy (CTE) is hypothesized to be a neurodegenerative disorder with deposition of hyperphosphorylated tau (p-tau) as neurofibrillary tangles. [27]. This disease is hypothesized to result from exposure to multiple TBI injuries over time and has been diagnosed in many different populations, particularly including elite athletes and military personnel [28, 29]. CTE is thought to develop years after being exposed to repeated head trauma with symptoms of irritability, impulsivity, aggression, depression, short-term memory loss and purportedly heightened suicidality [30]. With a more advancing disease, more severe neurological changes purportedly develop to include dementia, gait and speech abnormality, and Parkinsonism. The late stages of the disease may be similar to Alzheimer's regarding frontotemporal dementia [31]. Some reports suggest 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 [32]. The overall quality of epidemiological studies supporting a relationship between TBIs and CTE is relatively poor. At present, there is insufficient quality evidence to support CTE as something beyond a pathological diagnosis.

Concussion: Concussion has been variously defined [33, 34]; in general medicine mTBI (mild traumatic brain injury) may be used as equivalent terms [35, 36]. For purposes of this guideline, concussion is defined as a prolonged 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 brainstem resulting in rotational and/or translational (i.e. angular and lateral) movement of the head resulting in immediate or delayed neurological symptoms that resolve sequentially over time. The implications of the biomechanical mechanisms, complex pathophysiology, and clinical phenotype have important implications on occupational medicine questions of fitness for duty, return to work, and pre-placement.

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 incrased risk of dementia in those sustaining TBI [37-42]. Often the diagnosis of mild cognitive impairment (MCI) is a predecessor of dementia [43, 44]. The risk of dementia after moderate brain injury has been estimated at 2.3-fold increased risk, and 4.5-fold after a severe head injury [38]. TBI in older veterans has been associated with a 60% increased risk [39]. Evidence after mild TBI is less strong [45, 46].

Functional Capacity Evaluation: A functional capacity evaluation (FCE) is a comprehensive battery of performance-based tests to determine an individual's ability to do work-like tasks and conduct activities of daily living.[47] An FCE may be done to identify an individual's willingness/ability to perform specific tasks associated with a job (job-specific FCE), or his or her willingness/ability to perform physical activities associated with any job (general FCE). The term "capacity" used in FCE may be misleading, as an FCE generally measures performance tolerance (current demonstrated ability) and effort, rather than capacity. 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 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 [48] [49], and MACE [50] [51]. If there are spine pain issues, usable tool(s) may include the Neck Disability Index,[52-59] Bournemouth Neck Disability Questionnaire,[60] Modified Oswestry Questionnaire,[61, 62] Patient Specific Functional Scale, and Roland-Morris Disability Questionnaire.[63, 64]

Resolution of physical findings (such as cognitive function, increased muscle tone, radicular symptoms, or weakness), 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.[65] Functional restoration refers to a full-day multidisciplinary program lasting from 3 to 6 weeks.[66] There also are work conditioning and work hardening programs that are utilized[67, 68] (see Chronic Pain guideline for further discussion).

Glasgow Coma Scale (GCS): The Glasgow Coma Scale is a neurological scale that provides an objective measure of the conscious state of a person for initial as well as subsequent assessment ([69]). Since 1974, the Glasgow Coma Scale has provided a practical method for bedside assessment of impairment of conscious level, the clinical hallmark of acute brain injury. The scale was designed to be easy to use in clinical practice in general and specialist units and to replace previous ill-defined and inconsistent methods. Forty years later, the Glasgow Coma Scale has become an integral part of clinical practice and research worldwide. Findings using the scale have shown strong associations with those obtained by use of other early indices of severity and outcome. However, predictive statements should only be made in combination with other variables in a multivariate model. Individual patients are best described by the three components of the coma scale; whereas the derived total coma score should be used to characterize groups. Adherence to this principle and enhancement of the reliable practical use of the scale through continuing education of health professionals, standardization across different settings, and consensus on methods to address confounders will maintain its role in clinical practice and research in the future. [69]

The GCS is scored between 3 and 15, 3 being the worst, and 15 the best. It is composed of three parameters: Best Eye Response, Best Verbal Response and Best Motor Response.

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.

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 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.[52-57, 59] 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.[52] However, the tool is not standardized and is frequently modified, making interpretations difficult.[70]

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 [71]. 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 [72]. TBIs frequently involve injuries to these structures. [73].

Occupational Therapy: Occupational therapy typically invovles 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 (ADL's), 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 for TBIs, various cognitive function tests are prominent examples of outcomes predictors used. 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 from learning handicaps, speech and communication problems to walking and balance impairments, all of which may have acute, subacute and/or chronic effects [14]. 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, imaging tests (e.g., CT scans), gender and cognitive tests [74] [75].

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 measuring S100B, a biomarker of TBI, 12-36 hours post-injury, length of coma (LOC), and posttraumatic amnesia (PTA) and headache [76] [77] [78]. 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) [79], [80]. 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 [81] [82]. 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, motivation, accurate self-awareness, and full acceptance of returning to work [79, 83, 84].

Passive Modality: Passive modalities refer to various types of treatment given by a provider 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, above). Forms of passive modality include massage, hydrotherapy (whirlpools, hot tubs, spas, etc.), ultrasound, and hot/cold compresses.

Parkinson, and Parkinson Pugilistica: Parkinson's disease (PD) is the second most common neurogenerative disorder next to Alzheimer's disease that has 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's disease is theorized to occur with increased incidence in cases of chronic traumatic encephalopathy, sometimes termed Parkinson Pugilistica (see above). [85-88]

Physical Therapy: The term "physical therapy" is used in ACOEM's *Guidelines* generically to mean physical medicine, therapeutic and rehabilitative evaluations and procedures (e.g., massage). Much of the available research uses this term generically. This 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 *Guidelines* are not meant to restrict physical therapy to being performed only by physical therapists.

TBI –Traumatic brain injury (TBI) is a nondegenerative, noncongenital insult to the brain 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 [89-91]. Menon [90] reported a consensus defintion that, "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 length of loss of concussion and the Glasgow Coma Score. 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.

Mild/moderate may thus be clinically defined as: persistent symptoms i.e. headache, dizziness, neurocognitive, sleep, behavioral for more than six months without evidence on standard or advanced neuroimaging studies e.g., CT, MRI, DTI MRI of structural or micro structural damage (i.e., SAH, ICH, DAI, SDH, EDH), however with evidence on neuropsychological testing of abnormalities (e.g., decreased processing speed, executive function, attention and concentration, learning and memory) and may include a significant drop in premorbid intelligence. There should be no evidence of malingering and other possible causes of the patients symptoms, e.g., medications, metabolic, substance abuse. Symptoms may worsen with cognitive and at times physical exertion. Severe TBI may then be clinically defined as having the same attributes as mild/moderate with additional evidence of neuroimaging damage.

Categories of TBI. There are multiple definitions for TBI and there is no clear consensus definition. There are 3 broad acuity categories of TBI commonly used (mild, moderate, severe) and often these definitions are dissimilar. Although there are multiple definitions for all categories, MTBI (mild TBI) seems to have the greatest degree of variation in its definition. Some experts equate mild TBI to concussion and others do not. Regardless, for purposes of definitions, to provide a basis for discussion of patient treatment based on severity, and recognizing there is potential overlap for some cases, nevertheless, the following definitions are used:

Mild TBI (MTBI) is defined as including at least one of [92]:

- The person was not unconscious or was unconscious for less than 30 minutes.
- Memory loss lasted less than 24 hours.
- The GCS was 13 to15

Moderate TBI is defined as [92]:

- The person was unconscious for more than 30 minutes and up to 24 hours.
- Memory loss lasted anywhere from 24 hours to 7 days.
- The GCS was 9 to 12.

Severe TBI if [92]:

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

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, some suggest that those with an intracranial bleed but otherwise categorized as "mild" should be categorized as "moderate." [93, 94] Others have suggested relying more heavily on neuropsychological impairment to classify severity [94] as well as for the determination of longer term impairments [95].

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. [96]. 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 medium nerve (ophthalmic (V_1), maxillary (V_2), mandibular (V_3)). This pain may be dull, sharp and/or shooting. reduced reflexes and some experience burning pain [97].

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 10 million people every year and an estimated 10% of these cases are work-related [16]. Additionally, the mechanisms of TBI injury 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 than for non-work-related TBI. A direct blow to the head is not required for a TBI to occur because rapid acceleration or deceleration is a TBI mechanism. Military populations incur both blast- and non-blast-related TBI [98-101]. The majority of work-related TBI cases are not fatal and are considered mild. [102]. Estimates of the proportions from various causes in the general population are provided in Figure 2.

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 [103-108] [109-115], as there is a propensity toward under-reporting pre-injury symptoms especially in mild TBI cases as well as high rates of similar symptoms in non-concussed individuals [105] [108, 109, 111, 113, 115]. Persistence of symptoms after TBI has been shown to be increased in those who are older [107, 116, 117], female [118], and had a more severe injury [107, 116, 117] [107, 119]. Yet, from an objective perspective, it is concerning that persistence of symptoms has been associated with alcohol [109, 116], drug use [109, 116], psychological/psychiatric history [109, 115, 116, 118], seeking compensation [115] and lower socioeconomic status [120]. Similar findings of worse outcomes with lower parental education, school achievement, and a history of learning problems, have been reported in pediatric TBI patients [107, 117] [121].

The ability to distinguish mild TBI from controls is reportedly only moderately successful [122]. One case series found insufficient effort in 45% of workers compensation TBI cases [123]. Effort has been reported to be more important than TBI injury severity ("diagnosis threat") [124-126] [127] [128, 129]. Similarly, a patient's perception of adverse consequences after mild TBI and/or stress are also important in the ongoing perception of symptoms persistence [127, 130, 131] [104] [110]. Stress, psychiatric history, low social support, low intelligence, anxiety and depression have all been found to predict persistence of symptoms after TBI [130, 132-135]. Worse return to work status has been reported among those who are older, had a lower Glascow Coma Score, had extremity injuries, had prior job instability, and have lower education [136].

Individual Factors

Male gender is a strong risk factor for TBI [137, 138]. Severity measures also indicate that men incur worse TBIs than women, as men accrue more lost work time, and incurred higher average health care

costs [139]. 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 [140]. Assaults are common in among youth, while falls are increasingly common with advancing age [138, 141]. Increasing age has been associated with a poorer outcome for TBI [142]. 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 [143]. Other risks, especially for delayed recovery include prior mental disorder(s), attention deficit disorder, ADHD, drug use and pre-existing intellectual and physical disabilities. There is no significant evidence yet shown for risks from lack of exercise, genetics [144], cardiovascular disease [145], and illness [146].

Psychosocial and Work Organizational Factors

Work-related TBI may be accompanied by physical, emotional and psychosocial costs. Depression, anxiety, sleep disturbance, fatigue inability to function socially, and other physical problems are negative consequences following TBI [115, 143, 147, 148]. Psychosocial characteristics, such as anxiety, depression, locus of control, and somatization have been used to assess impacts affecting those sustaining TBI injuries [118, 149]. Sleep problems and fatigue commonly affect all categories of TBI patients [150, 151] 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 [152]. Comparatively minimal emotional issues are reported after mild TBI [153]. After TBI, inadequately addressing safety, poor social support, and financial burdens of injury may all influence returning to work [154].

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. [155]. Yet, it has also been reported that mild TBI is not adversely impacted by PTSD and other psychiatric disorders in veterans [156].

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 severe TBI patients 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.

In one report, approximately half of a group of 175 TBI patients that had prior employment were not able to return to work due to physical limitations [157]. One factor making return to work more difficult

for some is the gradual enlargement, and thus complexities of many jobs to include far more tasks than in prior decades.

Correlations between questionnaire(s), clinical assessment, physical examination, and self-assessment is needed to validate a TBI patient's current physical limitations prior to determining a return to work status [158].

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. 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.

Table 2. Red Flags for Potentially Serious TBI (including Neck/Thoracic Spine Conditions)

Disorder	Medical History	Physical Examination/Diagnostic Testing
SPINAL DISORDERS		
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 Organ-system relevant physical examination features if history of focal intracranial damage or bleeding
Intracerebral hemorrhages	Headache Nausea & 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[159] [159] 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)

Adapted from van den Hoogen 95; Jarvik 02; Bigos 94.[160-162] , Silbert 95 (1517-22), Hurwitz 96 (1746-61), Grad 1989 (281-4), Szmirnai 2001 (68-71), Bruce 2001(688-93), Berger 99 (175-81), Snyder 93 (253-8), Zaki 93 (110-12), Forsyth 93 (1678-83), Hiroki 2003 (34-100), Hong 2003 (210-14)

Absence of Red Flags

Absent red flags, TBI can be classified into one of three working categories:

Mild TBI, which includes at least one of [92]:

- The person was not unconscious or was unconscious for less than 30 minutes.
- Memory loss lasted less than 24 hours.
- The GCS was 13 to 15

Moderate TBI, which includes [92]:

- The person was unconscious for more than 30 minutes and up to 24 hours.
- Memory loss lasted anywhere from 24 hours to 7 days.
- The GCS was 9 to 12.

Severe TBI, which includes [92]:

- The person was unconscious for more than 24 hours.
- Memory loss lasted more than 7 days.
- 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 shown to persist up to a year [163]. Some patients can display symptoms beyond one year post-injury [164] [165, 166]. 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.

Diagnosis

Initial Assessment

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 [167].

There also are potential psychological conditions 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.

Medical History

As TBI clinical presentations are so varied, comprehensive medical histories and physical examinations are necessary to assess the patient's TBI [168]. 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(ies), age, past medical history, underlying medical conditions, prior injury history and genetic predilections all probabilistically adjust the diagnostic approach and prognoses [169].

As the history especially in subacute and chronic TBI patients may sometimes be unreliable [103, 105, 107-109], a suggested approach to consider is to: [170] 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) obtaining a retrograde clinical history, from recent to remote. [108]

Questions may include the following:

- When were you injured? How? What happened?
- Did you lose consciousness? For how long?
- Do you have any memory of what happened? For how much time are you missing your memory or have amnesia?
- Inquire specifically about each symptom or area of symptoms below, since individuals with TBI may have difficulty organizing and communicating their symptoms without prompting. Document results, whether subtle or pronounced, so that the there is a baseline status recorded, as well as the potential for subsequent comparisons. For each of the following symptoms that is present, answer specific questions asked.
- What is the frequency, severity, and duration of headaches? Are they throbbing or ice-pick or squeezing/tension-like?
- Is there dizziness or vertigo? How often? How severe?
- Is there weakness or paralysis? Where? When did that start?
- Are there vision problems? Can you see out of both eyes? What can't you see?
- Are there hearing problems? Ringing in the ears (one or both)?
- Are there balance problems?
- If ambulatory, are there any problems walking?
- Are there memory problems? What have you noticed?
- Are there problems thinking?
- Do you have difficulty concentrating?
- Do you have difficulty with executive functions (speed of information processing, goal setting, planning, organizing, prioritizing, self-monitoring, problem solving, judgment, decision making, spontaneity, and flexibility in changing actions when they are not productive)
- Do you have speech or swallowing difficulties? Expressive aphasia? Difficulty with articulation?
- Do you have pain? What is the severity, duration, location? Does pain radiate?
- Do you have bowel or bladder problems?
- Do you have a history of any psychological or psychiatric issues? Mood swings, anxiety, depression, other (describe)?
- Do you have a history of substance use? What type? Last use(s)?
- Do you have any sensory changes, such as numbness or paresthesias? Location and type?
- Any decreased sense of taste or smell?
- Any history of recent or past seizures? What type, how often? When last experienced?
- Do you have any symptoms of (autonomic dysfunction, such as) heat intolerance, excess or decreased sweating, etc.
- other symptoms, including symptoms of endocrine dysfunction or cranial nerve dysfunction – describe.

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 [103, 105, 107-109] [171]. Under-reporting of pre-injury symptoms is reportedly problematic [105, 109]. 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 [109].

As cervical spine trauma is often present with TBI, the following questions regarding the cervical spine are included.

1. What are your symptoms?
   - Do you have pain or stiffness?
   - Do you have numbness or tingling?
   - For traumatic injuries: Was the area deformed? Did you lose any blood or have an open wound?
   - Is the discomfort located primarily in your neck? In your arm?
   - Do you have pain or other symptoms elsewhere? (Patients who present with a primarily with upper extremity pain may well have radiculopathy from a cervical disc herniation or other spine pathology.)
   - When did your symptoms begin? Have you ever had symptoms like this before?
   - Are your symptoms constant or intermittent? What makes the problem worse or better?
   - What is the day pattern to your pain? Are you better first getting out of bed in the morning, during the morning, mid-day, evening, or while asleep? Worse as the day progresses? Do you have a problem sleeping? What position is most comfortable? Is there any pain with cough, sneezing, deep breathing, or laughing?
   - How long can you sit, stand, walk, and bend?
   - Can you lift? How much weight (use items such as gallons of milk, groceries, etc., as examples)?
2. How did your condition develop?

   Past:

   Have you had similar episodes previously?
   Have you had previous testing or treatment? With whom?

   Cause:

   What do you think caused the problem?
   How do you think it is related to work?
   Did your symptoms begin gradually or suddenly? Did you notice the pain the day after the event?
   Did you slip, trip, or fall?
   Were you doing anything at the time your symptoms began? (It is important to obtain all information necessary to document the biomechanical forces of injury.)

   Job:

   What are your specific job duties?
   How long do you spend performing each duty on a daily basis?
   Do you have assistance of other people or lifting devices?

   Off-work Activities:

   What other activities (hobbies, workouts, sports) do you engage in? At home or elsewhere?
   Any heavy lifting? How? How often?
   Any physically demanding activities requiring awkward postures, prolonged sitting or standing?

   How do these symptoms limit you?
   What activities of daily living are limited? Are there specific challenges in your home environment (e.g., steep steps)?
   How long have your activities been limited? More than 4 weeks?
   Have your symptoms changed? How?

3. Do you have other medical problems?
4. What are your expectations regarding your return to work and disability from this health problem?
5. What are your concerns about the potential for further injury to your neck as you recover?
6. What is your job? What do you do on the job? How do you like your job? Your supervisor and coworkers? What is your relationship with your co-workers and supervisor and how do they treat you?
7. What do you hope to accomplish during this visit?

Physical Exam

The objective of the initial physical examination of the TBI patient 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 [172]. 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. 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, psychological evalution and cognitive assessment should generally be performed [168]. 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 testing (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 [173].

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. Assess smooth pursuits and near point convergence. Assess qualitative hearing. Perform otoscopic exam.

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, 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).

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 in those with longer-term TBI [174] [175].

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 TBI patients 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 [176] Green 01 [125, 128].

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**. 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)) 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 [95] [168].

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.**

As 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

The most important neurologic deficit to recognize is myelopathy from spinal cord compression. 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, and some have bowel or bladder control impairment [177].

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, particularly congenital.

The neurologic examination most commonly focuses on a few tests that reveal evidence of nerve root impairment, peripheral neuropathy, or spinal cord dysfunction. 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.

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.

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 1cm. 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 pathologic reflex in combination with clonus may indicate an upper motor neuron lesion.

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 (3^{rd} 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 (5^{th} 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 [178].

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 non-specific 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.

Diagnostic Recommendations

Basic Imaging

Skull radiography has been used to diagnose fractures, and thus assessing in the evaluation of TBI patients. [188] [189] [190].

Skull X-Rays

Recommended.

Skull radiography is recommended for the evaluation of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Indications:	Head trauma thought to be sufficiently forceful to potentially fracture the skull. Indicated as well for further evaluation of bony step-offs and other clinical signs of fracture.
Benefits:	Identification of fracture, which helps to suggest severity of the injury and potential severity of TBI.
Harms:	Negligible
Frequency/Dose/Duration:	Generally only obtained at presentation. Occasionally re-xrayed at followup.
Rationale:	There is one study suggesting no significant differences between a 2-view and 3-view skull series [191]. Skull X-Rays are not invasive, have no adverse effects, are low cost, are helpful in diagnosing skull fractures and thus are recommended for evaluating TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: skull radiography, skull x-ray, head x-ray; brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; sensitivity, specificity, predictive value of tests, gold-standard, accurate, accuracy, precision, precise, or test. We found and reviewed 1247 articles in PubMed, 81 in Scopus, 42 in CINAHL, 42 in Cochrane Library, 13800 in Google Scholar, and 4 from other sources. We considered for inclusion 7 from PubMed, 2 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 4 from other sources. Of the 15 articles considered for inclusion, 1 diagnostic study and 2 systematic studies met the inclusion criteria.

Computed Tomography (CT)

Recommended.

Computed tomography is recommended for the evaluation of TBI patients.
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 injury(ies). Generally not indicated after the initial evaluation, as MRI is generally preferred for subacute to chronic brain parenchymal evaluation. [199] [200-205]. 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% [198]. The Canadian Head CT rule for indications for CT scans among those with Glasgow coma Score of 13-15 are: high-risk are GCS<15 at 2hrs 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% [198]. 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 of the 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 unstable patients. Scoring with the Helsinki score is reportedly superior to the Rotterdam and Marshall scores [206].
Harms:	Radiological exposure. May miss non-hemorrhagic abnormalities for which MRI is superior to CT for evaluation [199-205].
Frequency/Dose/Duration:	Generally only obtained at presentation or at the initial, comprehensive evaluatioan.
Rationale:	There are quality studies assessing CT for diagnosis of TBI. CT is particularly useful for unstable patients with potential need of surgical intervention. 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 treatment planning 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: x-ray computed tomography, computed tomography, computerized tomography, CT scan, CAT scan, computerized axial tomography, traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 2,462 articles in PubMed, 773 in Scopus, 468

in CINAHL, 3,290 in Cochrane Library, 53,400 in Google Scholar, and 16 from other sources. We considered for inclusion 4 from PubMed, 1 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 16 from other sources. Of the 23 articles considered for inclusion, 11 diagnostic studies, 2 prognostic studies and 7 systematic studies met the inclusion criteria.

Magnetic Resonance Imaging (MRI)

Moderately Recommended.

Magnetic resonance imaging is moderately recommended for the evaluation of TBI patients.
Strength of Evidence – **Moderately Recommended, Evidence (B)**
Level of Confidence – High

Indications:	Head trauma thought to be sufficiently forceful to potentially cause intracranial hemorrhage, epidural hemorrhage, subdural hemorrhage and/or other traumatic brain injury(ies). May be indicated for a followup MRI study for evaluation of ongoing symptoms, to assess a missed diagnosis, and/or resolution of prior defects.
Benefits:	Identification of surgical emergencies, fractures, and assisting in identifying or suggesting the severity of the TBI.
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 [209] [210].
Frequency/Dose/Duration:	Generally only obtained at presentation. Sometimes obtained to evaluate ongoing symptoms to assess a missed or secondary diagnosis.
Rationale:	There are multiple moderate quality studies suggesting utility of MRI for evaluation of TBI patients. MRI is reportedly superior to CT for assessing intracranial injuries, especially those without hemorrhage [199-204]. MRIs are not invasive (or minimally invasive with I.V. contrast), have no adverse effects, are high cost, but are helpful in diagnosing surgical emergencies and evaluation of the extent of TBI injury(ies) and are thus recommended for evaluating TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Magnetic Resonance Imaging OR MRI AND Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 1612 articles in PubMed, 891 in Scopus, 450 in CINAHL, 102 in Cochrane Library, 15700 in Google Scholar, and 0 from other sources. We considered for inclusion 6 from PubMed, 2 from Scopus, 3 from CINAHL, 1 from Cochrane Library, 1 from Google Scholar, and 25 from other sources. Of the 38 articles considered for inclusion, 31 diagnostic studies and 2 systematic studies met the inclusion criteria.

Advanced Imaging

Magnetic resonance spectroscopy (MRS) is a noninvasive diagnostic tool similar to MRI with the additional capability of measuring the metabolite concentrations [211-220].

Magnetic Resonance Spectroscopy (MRS)

No Recommendation.

There is no recommendation for or against the use of magnetic resonance spectroscopy for the evaluation of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are quality studies assessing MRS for diagnosis of TBI. There is consistent, quality evidence that MRS findings are correlated with TBI [221-226]. There also is evidence that MRS findings are predictive of subsequent clinical outcomes [221] [222]. Some evidence suggests intelligence factors may confound or interact with the MRS findings [224]. One comparative study reported higher sensitivity with SPECT than MRS [227]. Still, there is no quality evidence that MRS alters the clinical course beyond that already obtained from MRI or other imaging. MRS is not invasive has no adverse effects, is high cost, and has evidence of diagnostic efficacy. Yet, without quality evidence it alters the clinical course, there is no recommendation for or against MRS for the diagnosis 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: Magnetic Resonance (MR) Spectroscopy, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, and Craniocerebral Trauma; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 72 articles in PubMed, 8 in Scopus, 28 in CINAHL, 6 in Cochrane Library, 50 in Google Scholar, and 8 from other sources. We considered for inclusion 7 from PubMed, 2 from Scopus, 2 from CINAHL, 1 from Cochrane Library, 1 from Google Scholar, and 8 from other sources. Of the 21 articles considered for inclusion, 16 diagnostic studies and zero systematic studies met the inclusion criteria.

Functional MRI

No Recommendation.

There is no recommendation for or against the use of functional MRI for the evaluation of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are a few quality studies assessing Functional MRI for diagnosis of TBI. However, there are no quality studies showing fMRI alters the clinical course compared with other diagnostic testing such as traditional MRI. Most studies utilizing fMRI have focused on working memory tasks and not for diagnostic purposes [228]). Functional MRI diagnostic test is minimally invasive, has no adverse effects, is high cost, but has no quality evidence of altering the clinical course and thus there is no recommendation for or against use of fMRI.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: fMRI, Functional MRI, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 1529 articles in PubMed, 146 in Scopus, 50 in CINAHL, 32 in Cochrane Library, 9430 in Google Scholar, and 0 from other sources. We considered for inclusion 5 from PubMed, 2 from Scopus, 3 from CINAHL, 1 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 11 articles considered for inclusion, 5 diagnostic studies and 1 systematic studies met the inclusion criteria.

Diffusion Tensor Imaging (DTI)

Recommended.

Diffusion tensor imaging is recommendation for the evaluation of TBI patients.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Low

Indications:	Symptoms of mild TBI, especially with somewhat unclear severity and need to perform imaging to assess ongoing symptoms to identify that there are no abnormalities consistent with TBI on DTI.
Benefits:	Able to help identify existence of abnormalities consisitent 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.
Frequency/Dose/Duration:	Single evaluation. Infrequently, second evaluation may be helpful to assess progress and/or residual changes.
Rationale:	There are quality studies assessing DTI for diagnosis of TBI. Most [250] [251, 252] but not all [253] studies suggest it may help identify abnormalities consistent with TBI injuries. One study found a need to adjust results by age, sex and GCS [254]. One study suggests DTI findings are clinically predictive [255] and another suggests long lasting changes are identifiable with DTI [256]. DTI is minimally invasive, has no adverse effects, is high cost, and has some evidence of diagnostic efficacy, thus it is selectively recommended for evaluation of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: DTI, Diffusion Tensor Imaging, Diffusion Functional Imaging, Diffusion Spectrum Imaging, DSI, Diffusion Weighted Imaging, DWI, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 324 articles in PubMed, 257 in Scopus, 80 in CINAHL, 18 in Cochrane Library, 13,900 in Google Scholar, and 0 from other sources. We considered for inclusion 5 from PubMed, 2 from Scopus, 1 from CINAHL, 1 from Cochrane Library, 1 from Google Scholar, and 16 from other sources. Of the 26 articles considered for inclusion, 23 diagnostic studies and 3 systematic studies met the inclusion criteria.

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 TBI patients [257-262].

Single-Photon Emission Computerized Tomography (SPECT)

No Recommendation.

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

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 [263], 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 [264] [265] [266] or not superior [267]. SPECT has been used to attempt to objectify subjective complaints [268] [269] [270]. A few studies suggest SPECT findings are predictive of clinical outcomes [271] [272] [268] [273] [274]. 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, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Single-photon emission computerized tomography, SPECT, SPECT scan, SPET, Single-Photon Emission Computer-Assisted Tomography, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma; Sensitivity and Specificity, Predictive Value of Tests, Gold-standard, accurate, accuracy, precision, precise, test; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 60 articles in PubMed, 40 in Scopus, 20 in CINAHL, 21 in Cochrane Library, 40 in Google Scholar, and 22 from other sources. We considered for inclusion 7 from PubMed, 2 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 22 from other sources. Of the 32 articles considered for inclusion, 30 diagnostic studies and 2 systematic studies met the inclusion criteria.

Positron Emission Test (PET)

No Recommendation.

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

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are few quality studies assessing PET for diagnosis of TBI. PET is not invasive, has no adverse effects, is low cost, has limited evidence of diagnostic efficacy in TBI [280] without quality evidence the test alters the clinical course and thus there is no recommendation for or against PET for diagnosis 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: Positron-Emission Tomography, Traumatic brain injury, Intracranial injury, Closed Head injury Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 20 articles in PubMed, 10 in Scopus, 10 in CINAHL, 10 in Cochrane Library, 30 in Google Scholar, and 5 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 5 from other sources. Of the 7 articles considered for inclusion, 6 diagnostic studies and 1 systematic studies met the inclusion criteria.

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 [281]. Digital subtraction angiography has been used to detect vessel injury after penetrating brain injuries [282].

Vascular Imaging Tests

Recommended.

Vascular imaging tests are recommended for the evaluation of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Indications:	Symptoms and/or signs consistent with vascular injury
Benefits:	Identify treatable condition(s)
Harms:	Adverse effects of the procedure, including bleeding, vascular injury for the invasive procedures.
Frequency/Dose/Duration:	Usually only one assessment is needed. Tests include diagnostic ultrasound, arteriography, magnetic resonance angiography (MRA) and CT.
Rationale:	There are few quality studies assessing Vascular Imaging Tests for diagnosis of and effects of TBI. Vascular Imaging tests are invasive have adverse effects, are high cost, have some evidence of diagnostic efficacy, and are selectively recommended for diagnosis of vascular problems associated 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: Vascular Imaging Tests, Arteriography, Venography, Noninvasive Vascular Assessment, NIVA, Brain Acoustic Monitor, Traumatic Brain Injury, Closed Head Injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 414 articles in PubMed, 0 in Scopus, 7 in CINAHL, 141 in Cochrane Library, 8980 in Google Scholar, and 1 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 1 from other sources. Of the 4 articles considered for inclusion, 2 diagnostic studies and 0 systematic study met the inclusion criteria.

Brain Acoustic Monitor (BAM)

No Recommendation.

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

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%) [283, 287]. 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, Scopus, CINAHL and Cochrane Library without date limits using the following terms: brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; Sensitivity and Specificity, Predictive Value of Tests, Gold-standard, accurate, accuracy, precision, precise, test**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 6 articles in PubMed, 1 in Scopus, 1 in CINAHL, 6 in Cochrane Library, 11400 in Google Scholar, and 5 in other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 in Google Scholar, and 5 from other sources. Of the 7 articles considered for inclusion, 1 diagnostic study, 2 prognostic studies and 1 systematic study met the inclusion criteria.

Electroencephalography

Electroencephalography (EEG) has been used to detect brain activity, propensity towards seizures, and has been used in the evaluation of TBI patients [288-295].

Electroencephalography (EEG)

Recommended.

Electroencephalography (EEG) is recommendation for use in the evaluation of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – High

Indications:	Known or suspected TBI injury. Evaluation of seizure-like activity or evaluation of risk of seizures. 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:	There are no quality studies assessing EEG in comparison with other commonly used tests for diagnosing the extent of TBI. EEG is not invasive, has no adverse effects, is moderate cost, and has utility in the diagnosis and management of seizures related to TBI and is thus recommended for diagnosis 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**;** Quantitative Electroencephalograph (QEEG), Electroencephalography (EEG). Brain Injuries, Head Injuries, Penetrating, Brain Concussion, Concussion, Craniocerenral Trauma, Traumatic brain, Intracranial, Closed Head, Penetrating, Head, Craniocerebral Trauma, Injury, and Injuries. (Diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 2 articles in PubMed, 0 in Scopus, 1 in CINAHL, 0 in Cochrane Library, 0 in Google Scholar, and 8 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 7 from other sources. Of the 10 articles considered for inclusion, 8 diagnostic studies and 1 systematic study met the inclusion criteria.

Electroencephalography

Quantitative electroencephalogram has been used to assess brain activity among TBI patients [288-295].

Quantitative Electroencephalograph (QEEG)

No Recommendation.

There is no recommendation for or against the use of quantitative electroencephalograph (QEEG) in the evaluation of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are no quality studies assessing QEEG in comparison with other commonly used tests for diagnosing the extent of TBI, and no quality evidence QEEG is meaningfully superior to EEG. QEEG is not invasive, has no adverse effects, is moderate cost, but has no clear superiority for evaluation of TBI patients 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**;** Quantitative Electroencephalograph (QEEG), Electroencephalography (EEG). Brain Injuries, Head Injuries, Penetrating, Brain Concussion, Concussion, Craniocerenral Trauma, Traumatic brain, Intracranial, Closed Head, Penetrating, Head, Craniocerebral Trauma, Injury, and Injuries. (Diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 2 articles in PubMed, 0 in Scopus, 1 in CINAHL, 0 in Cochrane Library, 0 in Google Scholar, and 8 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 7 from other sources. Of the 10 articles considered for inclusion, 8 diagnostic studies and 1 systematic study met the inclusion criteria.

Evoked Potentials

Somatosensory evoked potentials have been used to determine if neurological damage has occurred from a traumatic brain injury [296-299].

Somatosensory Evoked Potential (SSEP)

Recommended.

Somatosensory evoked potentials (SSEP) are recommended for use in the evaluation of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Severe TBI with inability to test sensory system with more common methods, such as bedside testing.
Benefits:	Ability to assess the sensory system
Harms:	Negligible
Frequency/Dose/Duration:	May be used at baseline. If there are abnormalities and the injury continues to preclude other testing, then followup testing with somatosensory evoked potentials is reasonable.
Indications for Discontinuation:	Resolution of TBI, improvement sufficient to undergo standard testing.
Rationale:	There are quality studies assessing Somatosensory Evoked Potential (SSEP) for diagnosis and followup of TBI. Somatosensory Evoked Potential (SSEP) testing is not invasive has no adverse effects, is low cost, has evidence of diagnostic efficacy, and is recommended for selective diagnosis and assessment 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: Somatosensory Evoked Potential, Traumatic Brain Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 19 articles in PubMed, 16 in Scopus, 1 in CINAHL, 1 in Cochrane Library, 2240 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Vestibular Evoked Myogenic Potentials

No Recommendation.

There is no recommendation for or against the use of vestibular evoked myogenic potentials to diagnose traumatic brain injury.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are no quality studies assessing Vestibular Evoked Myogenic Potentials for evaluation of TBI. Vestibular Evoked Myogenic Potentials is not invasive, has no adverse effects, is low cost, but

	absent quality evidence of diagnostic efficacy, there is no recommendation for evaluation 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 evoked myogenic potentials, VEMP, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 5 articles in PubMed, 5 in Scopus, 2 in CINAHL, 1 in Cochrane Library, 582 in Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.
Comments:	

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 [300].

EMG and Nerve Conduction Studies

Recommended.

Electromyography and nerve conduction studies are recommended for the evaluation of TBI.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Indications:	Known or suspected peripheral nerve injuries or CNS injuries with peripheral nerve sequelae (e.g., identification of extent of partial paralysis).
Benefits:	Identification and quantification of peripheral nerve injury(ies). 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 EMG/NCS for diagnosis of peripheral nerve injury(ies) or consequences of central nervous system injury(ies) associated with TBI, although there are a few quality studies for evaluation of the distal upper extremity (see Hand, Wrist Forearm Guideline). facial nerve injury from TBI. EMG/NCS is minimally invasive, has no adverse effects, is moderate to high cost depending on extent of the examination required, and is thought to aid in the identification of either peripheral nerve injury(ies) and/or peripheral consequences of central nervous system insults from TBIs and thus 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: Electromyogram, EMG, Nerve conduction studies, Traumatic brain injury Closed Head injury,

Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 14 articles in PubMed, 62 in Scopus, 3 in CINAHL, in Cochrane Library, 16 in Google Scholar, and zero from other sources. Zero articles met the inclusion criteria.

Electrodiagnostic Studies

Electroneuronography (ENoG) is a neurological test that assess the integrity and ability of the facial nerves. The purpose of ENoG is to quantify the percentage of nerve fibers that can be stimulated [301]. The assessment of the facial is thought to be useful in managing facial nerve disorders and identifying disorders that affect facial nerves.

Electroneuronography (EnoG)

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Known or suspected facial nerve injuries.
Benefits:	Identification and quantification of facial nerve injury(ies). 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. EnoG is minimally invasive, has no adverse effects, is moderate cost, and is thought to aid in the identification of facial nerve injury and thus is selectively recommended to identify facial nerve injuries associated 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: electroneurography Electroneuronography, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 11 articles in PubMed, 16 in Scopus, 0 in CINAHL, 1 in Cochrane Library, 10 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Ultrasound

Ultrasonography

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Head trauma thought to be sufficiently forceful to potentially fracture the skull.
Benefits:	Identification of fracture, which helps to suggest severity of the injury and potential severity of TBI.
Harms:	Negligible
Frequency/Dose/Duration:	Generally only obtained at presentation.
Rationale:	There are no quality studies assessing Ultrasonography for diagnosis of TBI. 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, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Ultrasonography, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 424 articles in PubMed, 151 in Scopus, 65 in CINAHL, 1 in Cochrane Library, 27900 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Post-Concussion and Sideline Testing

Multiple concussion screening tests are typically used on the sidelines of contact sports to manage concussion injuries [302-309]. These include but are not limited to ImPACT, MACE, King-Devick and SCAT. [310-312]. 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.

Immediate Post-Concussion Assessment (ImPACT)

No Recommendation.

There is no recommendation for or against the use of Immediate Post-Concussion Assessment (ImPACT) in the evaluation of TBI patients.
Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are a few quality studies assessing ImPACT for diagnosis of TBI [302, 305-307], although it is cumbersome to use and nearly all data

	are from adolescent or young adult athletes raising questions about the applicability to occupational settings and its overall utility is disputed [313]. While the body of evidence suggests some some utility for this tool, the studies somewhat conflict regarding the overall sensitivity of the test. 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 [314-317]. The ImPACT diagnostic test is not invasive, has no adverse effects, is low cost, has somewhat conflicting 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 Traumatic brain injury, Intracranial injury, Closed Head injury Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma; Sensitivity and Specificity, Predictive Value of Tests, Gold-standard, accurate, accuracy, precision, precise, test**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 934 articles in PubMed, 26 in Scopus, 18 in CINAHL, 10 in Cochrane Library, 0 in Google Scholar, and 0 from other sources. We considered for inclusion 4 from PubMed, 2 from Scopus, 2 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 2 diagnostic studies, 4 prognostic studies and 1 systematic study met the inclusion criteria.

Military Acute Concusssion Evaluation

No Recommendation.

There is no recommendation for or against the use of Military Acute Concusssion Evaluation in the evaluation of TBI patients.

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 occupational populations. There is one study that attempted to determine utility of the MACE in a military population and suggests some discriminatory ability [310]. The MACE diagnostic test is not invasive, has no adverse effects, is low cost, but has no documented evidence of diagnostic efficacy in typical employed populations, and thus there is no recommendation regarding its use 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, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Military acute concussion evaluation, MACE, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 13 articles in PubMed, 2 in Scopus, 6 in CINAHL, 0 in Cochrane Library, 7830 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 articles considered for inclusion, 1 prognostic study and 0 systematic studies met the inclusion criteria.

King-Devick (K-D)

The King-Devick screen is recommended for use in the evaluation of TBI patients.

Recommended.

Strength of Evidence – **Recommended, Evidence (C)**

Level of Confidence – Low

Indications:	Mild, moderate or severe TBI patients or athletes. Generally used among those with a known baseline measurement. King-Devick is a visual performance test to and has been used most often in contact sport athletes to enhance the detection of 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 reads the numbers on 3 test cards with the score being the total time required in seconds [339].
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
Frequency/Dose/Duration:	Baseline evaluation. Then measured after subsequent potential TBI event(s).
Indications for Discontinuation:	N/A
Rationale:	There are several moderate quality studies assessing King-Devick for diagnosis of sports related concussion [323, 326-331, 333] [334] [335] [340] [337, 338] although most data are from adolescent or young adult athletes raising questions about the applicability to occupational settings. While the body of evidence suggests some utility for this tool, the studies somewhat conflict regarding the overall sensitivity of the test. The King-Devick diagnostic test is not invasive, has no adverse effects, is low cost, has somewhat conflicting evidence of efficacy, but has moderate evidence suggesting prognostic utility and thus is recommended for evaluation of mild-moderate to severe TBI. King-Devick testing may be performed at the rapidly by non-professional individuals.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms Traumatic brain injury, Intracranial injury, Closed Head injury Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma; Sensitivity and Specificity, Predictive Value of Tests, Gold-standard, accurate, accuracy, precision, precise, test**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 934 articles in PubMed, 26 in Scopus, 18 in CINAHL, 10 in Cochrane Library, 0 in Google Scholar, and 0 from other sources. We considered for inclusion 4 from PubMed, 2 from Scopus, 2 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 2 diagnostic studies, 4 prognostic studies and 1 systematic study met the inclusion criteria.

Sport Concussion Assessment Tool (SCAT)

Recommended.

The Sport Concussion Assessment Tool (SCAT) is recommended for use in the evaluation of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	The SCAT is a screening evaluative tool and not a diagnostic tool. Use of possible post-TBI testing. Repeat testing to follow progress may also be helpful.
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 after TBI and monitored periodically during recovery. For high risk situations, baseline or pre-concussion testing may help measure the baseline [344]. Baseline, pre-TBI testing would rarely be indicated in occupational settings.
Rationale:	There are quality studies assessing SCAT for diagnosis of TBI [345] [312, 346]. One comparative study suggested the SCAT 2 is superior to the MACE [312]. One study suggested utility of SCAT, although it also found differences by age and gender, potentially rendering interpretations more challenging [345]. The SCAT diagnostic test is not invasive has no adverse effects, is low cost, has some evidence of diagnostic efficacy, and is recommended for diagnosis and follow-up testing 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: SCAT, sport concussion assessment tool, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 50 articles in PubMed, 40 in Scopus, 20 in CINAHL, 3 in Cochrane Library, 20 in Google Scholar, and 1 from other sources. We considered for inclusion 6 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 1 from other sources. Of the 8 articles considered for inclusion, 1 diagnostic study, 3 prognostic studies and 4 systematic studies met the inclusion criteria.

Neuropsychological Assessment

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 TBI patients [303, 304, 347, 348]. Neuropsychological assessments frequently include analyses of effort and signs of exaggeration.

Neuropsychology occupies a prominent role in the evaluation and treatment of TBI patients, 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 mild TBI patients with persistent symptoms beyond one month. Neuropsychology is 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 [93, 95, 349-352]. 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, TBI patients. 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

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**

Level of Confidence – High

Indications:	Moderate or Severe TBI patients experiencing cognitive difficulties. Mild TBI patients 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 evalulations are widely considered indispensable for evaluation of TBI impairments [95].
Benefits:	Identify and measure psychological, neuropsychological, social, behavioral and cognitive capabilities, potentially allowing better tailoring of therapy(ies) to address the specific deficit(s).
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. May be used to target specific rehabilitation strategies. May later help determine end of healing and extent of residual deficits, if any.

Rationale: Neuropsychological Assessments are not invasive, have no adverse effects, are moderately costly, are thought to be effective for evaluation of TBI patients and are thus recommended for the evaluation of TBI patients. Tests that are used should utilize the most recent versions.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Neuropsychological Assessment, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 20 articles in PubMed, 10 in Scopus, 10 in CINAHL, 10 in Cochrane Library, 10 in Google Scholar, and 0 from other sources. We considered for inclusion 8 from PubMed, 4 from Scopus, 5 from CINAHL, 4 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 22 articles considered for inclusion, 9 diagnostic studies and 8 systematic studies met the inclusion criteria.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Neurocognitive testing, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 181 articles in PubMed, 580 in Scopus, 37 in CINAHL, 28 in Cochrane Library, 60 in Google Scholar, and 2 from other sources. We considered for inclusion zero from PubMed, one from Scopus, one from CINAHL, zero from Cochrane Library, zero from Google Scholar, and 2 from other sources. Of the 4 articles considered for inclusion, 4 diagnostic studies and zero systematic studies met the inclusion criteria.

The MMPI-2 (also MMPI-2-RF) has been widely used to assist in comprehensive psychological evaluations, including those of persons with traumatic brain injury [353-358]. Its use has been reported among TBI patients, including for the identification of malingering and/or exaggeration.

Personality/Psychological Assessment

Minnesota Multiphasic Personality Inventory (MMPI)

Recommended.

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

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – **Moderate**

Indications:	Post-TBI testing. Repeat testing to follow progress may sometimes be helpful. There may be limited indications in mild TBI patients.
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 malingering [253, 359-364] [365]. 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 quality studies assessing MMPI for evaluation of patients who sustained TBI. The MMPI is not invasive, has no adverse effects, is moderate cost, has evidence of accuracy especially for detecting malingering, and is thus recommended for evaluation of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Minnesota Multiphasic Personality Inventory (MMPI) and Hs (Hypochondriasis) and Hy (Hysteria)**;** Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 122 articles in PubMed, 92 in Scopus, 14 in CINAHL, 14 in Cochrane Library, 430 in Google Scholar, and zero from other sources. We considered for inclusion 13 from PubMed, zero from Scopus, 2 from CINAHL, one from Cochrane Library, zero from Google Scholar, and zero from other sources. Of the 15 articles considered for inclusion, 2 prognostic studies, 11 diagnostic and 2 systematic studies met the inclusion criteria.

Intelligence Testing

Wechsler Adult Intelligence Scale

Recommended.

The Wechsler Adult Intelligence Scale is moderate recommended for use in the evaluation of TBI patients.

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 malingering. [372-376] [377-380]. 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 utlity of WAIS and/or WAIS-IV for evaluation of patients who sustained TBI [372-375] [376-378] [379, 380]. WAIS is not invasive, has no adverse effects, is of moderate cost, has evidence of accuracy for assessing IQ and for detecting malingering, and is thus recommended for evaluation of TBI patients. The test is periodically updated and the most recent version 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: Minnesota Multiphasic Personality Inventory (MMPI) and Hs (Hypochondriasis) and Hy (Hysteria)**;** Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 122 articles in PubMed, 92 in Scopus, 14 in CINAHL, 14 in Cochrane Library, 430 in Google Scholar, and zero from other sources. We considered for inclusion 13 from PubMed, zero from Scopus, 2 from CINAHL, one from Cochrane Library, zero from Google Scholar, and zero from other sources. Of the 15 articles considered for inclusion, 2 prognostic studies, 11 diagnostic and 2 systematic studies met the inclusion criteria. Traumatic Brain Injury– A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Wechsler Adult Intelligence Scale-III, WAIS-III, WAIS-IV, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 42 articles in PubMed, 21 in Scopus, 18 in CINAHL, 17 in Cochrane Library, 2480 in Google Scholar, and 2 from other sources. We considered for

inclusion 12 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 2 from other sources. Of the 14 articles considered for inclusion, 14 diagnostic and 0 systematic studies met the inclusion criteria.

Automated Neuropsychological Assessment Metrics

Moderately Recommended.

Automated Neuropsychological Assessment Metrics is moderately recommended for use in the evaluation of TBI patients.

Strength of Evidence – **Moderately Recommended, Evidence (B)**
Level of Confidence – Moderate

Indications:	Post-TBI testing. 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 [397].
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 several quality studies assessing ANAM for diagnosis of TBI [393, 397-403]. All studies suggest utility of ANAM for diagnosis and/or prognosis, although the populations assessed in the quality studies are largely military. Some studies were primarily of athletes. The ANAM diagnostic test is not invasive has no adverse effects, is low cost, has evidence of diagnostic efficacy, and is recommended for diagnosis of TBI.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Google Scholar, and Cochrane Library without date limits using the following terms: automated, neuropsychological, assessment, metrics, ANAM, neck, neck pain, cervical, radicular pain or radiculopathies, neck pain diagnosis, diagnostic, diagnosis, sensitivity, specificity, positive and negative predictive value, predictive value of tests, vertebrae or vertebral or spine; brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; Sensitivity and Specificity, Predictive Value of Tests, Gold-standard, accurate, accuracy, precision, precise, test**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 18 articles in PubMed, 13 in Scopus, 13 in CINAHL, 3 in Cochrane Library, 3460 in Google Scholar, and 0 in other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar and 15 from other sources. Of the 17 articles considered for inclusion, 15 diagnostic studies and 0 systematic studies met the inclusion criteria.

Memory, Malingering, Exaggeration & Poor Effort Testing

Memory tests have been used to assess TBI patients [404-418]. There are many different types of memory tests used, including: Everyday Memory Questionnaire (EMQ), Spatial Recall Test [409] Short Orientation Memory and Concentration Test (SOMC) [406], Recognition Memory Tests (RMT) [410], the Wechsler Memory Scale (WMS), standardized assessment of concussion (SAC) (O'Neil 14; McCrea 97,98,01; Barr 01;Yan 17), Montreal Cognitive Assessment (MOCA) (deGuise 13,14; Zhang 16a,b; Lim 16), as well as many others.

Malingering tests have been used to assess TBI patients [361, 364, 368, 369, 371, 372]. In addition to tests specifically designed to assess effort and malingering, 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 various different types of malingering tests used, including: the Test of Memory Malingering (TOMM) [371] [414], Word Memory Test (WMT) [361], the Portland Digit Recognition Test [168], Reliable Digit Span test (Hall 2014), the Wisconsin Card Sorting test [372], as well as others.

Memory and Malingering Tests

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Indications:	Moderate or Severe TBI patients 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 mild TBI patients, 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 therapy(ies) to address any memory deficits. Malingering tests used to identify and measure intentional production of exaggerated or false symptoms.
Harms:	Negligible in most patients. Memory testing is strongly subject to malingering and many comparative studies exclude all patients involved in any litigation. Thus, careful interpretation and potential pairing with tests for malingering 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. There are also quality studies assessing Malingering Tests fo diagnosis of 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 malingering 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 TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: memory test, letter memory or test of memory malingering or word memory test, traumatic brain injury, intracranial injury, closed head injury penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; sensitivity and specificity, predictive value of tests, gold-standard, accurate, accuracy, precision, precise, test; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 941 articles in PubMed, 546 in Scopus, 793 in CINAHL, 4 in Cochrane Library, 10200 in Google Scholar, and 1 from other sources. We considered for inclusion 11 from PubMed, 3 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 6 from Google Scholar, and 1 from other sources. Of the 21 articles considered for inclusion, 15 diagnostic studies and 0 systematic studies met the inclusion criteria.

California Verbal Learning Test (CVLT-I and CVLT-II)

Recommended.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**

Level of Confidence – Moderate

Indications:	Generally used in mild TBI patients, particularly for evaluating learning, memory and malingering.
Benefits:	Assess memory and learning. Identification of malingering.
Harms:	Negligible
Frequency/Dose/Duration:	Generally used on one occasion if use is for detecting malingering. 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 malingering [420, 421]. One moderate quality study suggests CVLT-II is more sensitive for memory measures than the Word Memory Test [422]. CVLT is not invasive, has negligible adverse effects, is low cost and is recommended for evaluation of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: California Verbal Learning Test Second Edition, CVLT-II; Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 36 articles in PubMed, 11 in Scopus, 5 in CINAHL, 18 in Cochrane Library, 20,400 in Google Scholar, and 0 from other sources. We considered for inclusion 7 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 8 articles considered for

inclusion, 8 diagnostic studies and 0 systematic studies met the inclusion criteria.

Repeatable Battery of the Assessment of Neuropsychological Status (RBANS)

Recommended.

The Repeatable Battery of the Assessment of Neuropsychological Status is recommended for use in the evaluation of TBI patients.
Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Patients with ongoing cognitive symptoms from TBI. May also be used to assess effort and malingering [423, 424].
Benefits:	Assess cognitive function in 5 domains. Malingering is potentially able to be evaluated with 2 subscales [423].
Harms:	Negligible
Frequency/Dose/Duration:	Generally used on one occasion if use is for detecting malingering. May be used on subsequent occasions to track learning and memory progress.
Rationale:	The highest quality studies suggest RBANS is useful for evaluating cognitive function [425, 426] and malingering [423, 424]. RBANS is not invasive, has negligible adverse effects, is low cost and is recommended for evaluation of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Repeatable Battery for the Assessment of Neuropsychological Status, RBANS; Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 17 articles in PubMed, 12 in Scopus, 12 in CINAHL, 21in Cochrane Library, 3,760 in Google Scholar, and 0 from other sources. We considered for inclusion 4 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 4 diagnostic studies and 0 systematic studies met the inclusion criteria.

Wechsler Memory Scale

Moderately Recommended.

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

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 malingering.
Benefits:	Identification of severity of TBI, follow-up of symptoms and at resolution of symptoms. May assist with identification of malingering. Often used in conjunction with WAIS-III as well as the clinical picture to attempt to substantiate subjective complaints. [430], [431]Langeluddecke, 2003 #2479}[124, 432-434].
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 [135, 427-429]. 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 TBI patients. The test is periodically updated and the most recent version 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: Minnesota Multiphasic Personality Inventory (MMPI) and Hs (Hypochondriasis) and Hy (Hysteria)**;** Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 122 articles in PubMed, 92 in Scopus, 14 in CINAHL, 14 in Cochrane Library, 430 in Google Scholar, and zero from other sources. We considered for inclusion 13 from PubMed, zero from Scopus, 2 from CINAHL, one from Cochrane Library, zero from Google Scholar, and zero from other sources. Of the 15 articles considered for inclusion, 2 prognostic studies, 11 diagnostic and 2 systematic studies met the inclusion criteria. A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Wechsler Adult Intelligence Scale-III, WAIS-III, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 42 articles in PubMed, 21 in Scopus, 18 in CINAHL, 17 in Cochrane Library, 2480 in Google Scholar, and 2 from other sources. We considered for inclusion 12 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 2 from other sources. Of the 14 articles considered for inclusion, 14 diagnostic studies and 0 systematic studies met the inclusion criteria.

Test of Memory Malingering (TOMM)

Recommended.

The Test of Memory Malingering is moderately recommended for use in the evaluation of TBI patients.

Strength of Evidence – **Moderately Recommended, Evidence (B)**

Level of Confidence – High

Indications:	Post-TBI testing. Repeat testing to follow progress may sometimes be helpful [435] [122, 168, 405, 436-445] [365, 411, 414] There may be select patients with ongoing symptoms from mild TBI who are candidates.
Benefits:	Identification of severity of TBI, follow-up of symptoms and at resolution of symptoms. May assist with identification of malingering and to attempt to substantiate subjective complaints.
Harms:	Negligible.
Frequency/Dose/Duration:	Administered after TBI, generally early in the clinical course. May be administered in evaluations at the point of maximum recovery.
Rationale:	There are several moderate quality studies assessing TOMM evaluation of patients who sustained TBI. This test is not invasive, has no adverse effects, is of moderate cost, has evidence of accuracy especially for detecting malingering in MTBI, and is thus recommended for evaluation of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Minnesota Multiphasic Personality Inventory (MMPI) and Hs (Hypochondriasis) and Hy (Hysteria)**;** Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 122 articles in PubMed, 92 in Scopus, 14 in CINAHL, 14 in Cochrane Library, 430 in Google Scholar, and zero from other sources. We considered for inclusion 13 from PubMed, zero from Scopus, 2 from CINAHL, one from Cochrane Library, zero from Google Scholar, and zero from other sources. Of the 15 articles considered for inclusion, 2 prognostic studies, 11 diagnostic and 2 systematic studies met the inclusion criteria.

Cognitive Event-Related Potential

Recommended.

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

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Low

Indications:	Post-TBI patients who either have symptoms of cognitive deficits and/or have sustained a TBI sufficient to cause same.
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 efficacy. 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.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Cognitive Event Related Potential, Event Related Potential, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 386 articles in PubMed, 88 in Scopus, 34 in CINAHL, 14 in Cochrane Library, 10100 in Google Scholar, and 12 from other sources. We considered for inclusion 4 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 2 randomized trials and 4 systematic studies met the inclusion criteria.

Attention Testing

Recent 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 [448], information processing speed [349, 449], maintain focus [450, 449], shift attention [451], attention span [449], supervisory attentional control [449], focused/selective attention [449], and sustain attention [449, 452]. Age was not found to be a significant factor by some [449] but not all studies [453].

However, Ginstfeldt [454] found that sustained attention was most vulnerable to TBI in children. There are many studies that have used attention testing in the evaluation of TBI patients [455, 456, 457, 458-474].

Attention Tests

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Indications:	Moderate or Severe TBI patients experiencing cognitive difficulties that include attention. 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 therapy(ies) to address any memory deficits.
Harms:	Negligible in most patients. Testing is strongly subject to malingering. Thus, careful interpretation and potential pairing with tests for malingering 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:	There are quality studies assessing Attention testing for diagnosis and evaluation of TBI. However, there are few comparative trials of sufficient size and rigor to allow a recommendation of one type of testing over another. Attention testing is not invasive, has no adverse effects, is low cost, has evidence of diagnostic efficacy, and thus is recommended for evaluation of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: attention test, sustained attention to response task or monotone counting or variables of attention test, traumatic brain injury, intracranial injury, closed head injury penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; sensitivity and specificity, predictive value of tests, gold-standard, accurate, accuracy, precision, precise, test; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed articles in 747 PubMed, 310 in Scopus, 496 in CINAHL, 4 in Cochrane Library, 25800 in Google Scholar, and 8 from other sources. We considered for inclusion 11 from PubMed, 8 from Scopus, 2 from CINAHL, 3 from Cochrane Library, 3

from Google Scholar, and 8 from other sources. Of the 35 articles considered for inclusion, 19 prognostic studies, 1 randomized trial and 5 systematic studies met the inclusion criteria.

Executive Function

Executive Function Test

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Indications:	Moderate or Severe TBI patients experiencing cognitive difficulties that include executive functions. Mild TBI patients are expected to have no durable executive dysfunction [126], 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 therapy(ies) to address any deficits.
Harms:	Negligible in most patients. Testing may be subject to malingering. Thus, careful interpretation and potential pairing with tests for malingering 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:	There are quality studies assessing Executive function testing for diagnosis of TBI. However, there are few comparative trials of sufficient size and rigor to allow a recommendation of one type of testing over another. Executive function testing is not invasive, has no adverse effects, is low cost, has some evidence of diagnostic efficacy, and is thus recommended for evaluation of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Executive Function Test, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma; Sensitivity and Specificity, Predictive Value of Tests, Gold-standard, accurate, accuracy, precision, precise, test diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 333 articles in PubMed, 10 in Scopus, 25 in CINAHL, 0 in Cochrane Library, 0 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 4 from Scopus, 3 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 9 articles considered for inclusion, 9 prognostic studies and 0 systematic studies met the inclusion criteria.

Vision Testing

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. **See Eye Guideline.**

Visual Acuity Testing

Recommended.

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

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:	There are no quality studies assessing Visual Acuity Testing for evaluation of TBI impairments. See also Eye 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 TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Visual Field Testing, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 51 articles in PubMed, 4 in Scopus, 1 in CINAHL, 3 in Cochrane Library, 40800 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria. A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Low Vision Evaluation, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 4 articles in PubMed, 12 in Scopus, 32 in CINAHL, 452 in Cochrane Library, 2290000 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 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 studies met the inclusion criteria.

Visual evoked potentials (VEPs) have been used to attempt to predict outcome after brain injury [297].

Visual Evoked Potentials (VEP)

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
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 followup testing with visual evoked potentials is reasonable.
Indications for Discontinuation:	Resolution of TBI, improvement sufficient to undergo standard vision testing.
Rationale:	There are no quality studies assessing Visual Evoked Response for diagnosis or evaluation of TBI. 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, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: evoked potential, evoked potential response, evoked potential responses, somatosensory evoked potential; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, efficiency, Gold-standard, accurate, and accuracy. We found and reviewed 74 articles in PubMed, 223 in Scopus, 34 in CINAHL, 19 in Cochrane Library, 6,360 in Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Visual Field Testing

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 [496].

Visual Field Testing

Recommended.

Visual field testing is recommended for use in the evaluation of TBI patients. **See Eye guideline.**

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 fields.
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 Field Testing for evaluation of TBI impairments. See also Eye 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 TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Visual Field Testing, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 51 articles in PubMed, 4 in Scopus, 1 in CINAHL, 3 in Cochrane Library, 40800 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Visual Perceptual Testing

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.

Visual Perceptual Testing

Recommended.

Visual perceptual testing is selectively used for severe TBI.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Generally only an issue with severe TBI. 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. 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 are selectively used for the evaluation of TBI patients.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Visual Perceptual Testing, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 10 articles in PubMed, 3 in Scopus, 47 in CINAHL, 3 in Cochrane Library, 10300 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Other Tests

Electroretinogram or ERG is typically not used as a reliable diagnostic tool for TBI.

Electroretinogram (ERG)

No Recommendation.

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

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 evidence of diagnostic efficacy in TBI patients, and thus there is no recommendation for evaluation of TBI patients.

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.

Fluorescein Angiography

Recommended.

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

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 TBI patients. Fluorescein angiography is minimally invasive, has no adverse effects, is moderate cost, and while there is not quality evidence of diagnostic efficacy in TBI patients, it is the gold standard for evaluation of the retinal blood supply and so is recommended for select evaluation of visual impairments associated 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: Fluorescein Angiography, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, Eye blood vessel imaging, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 19 articles in PubMed, 0 in Scopus, 0 in CINAHL, 0 in Cochrane Library, 6860 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

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 [497].

Optical Coherence Tomography

No Recommendation.

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

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are no quality studies assessing Optical Coherence Tomography for evaluation of TBI. Optical Coherence Tomography is not invasive,

	has no adverse effects, is low cost, but in the absence of diagnostic efficacy, there is no recommendation for diagnostic evaluation 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: Optical Coherence Tomography, Traumatic Brain Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 26 articles in PubMed, 15 in Scopus, 1 in CINAHL, 1 in Cochrane Library, 6,390 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Audiometry/Otology

Damage to the hearing structures is a common effect of a TBI. Conducting Audiological tests to assess the level of damage may be useful in identifying hearing impairments and other disorders affiliated with TBI [498].

Audiometry

Recommended.

Audiometry is recommended for use in the evaluation of TBI patients.

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 TBI patients with audiometry.
Benefits:	Identification and quantification of hearing deficits. Potential to identify candidate 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:	There are few quality studies assessing Audiometry for diagnosis and evaluation of TBI, yet there is extensive evidence for evaluation of hearing for other conditions and audiometry is considered the gold standard for evaluation of hearing. Audiometry is not invasive, has no adverse effects, is low cost, has evidence of diagnostic efficacy, and is recommended for diagnosis of hearing impairments from TBI.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Audiometry AND Traumatic Brain Injury, Closed head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 63 articles in PubMed, 11 in Scopus, 22 in CINAHL, 2 in Cochrane Library, 7250 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 articles considered for inclusion, 1 randomized trials and 0 systematic studies met the inclusion criteria.

Brainstem Auditory Evoked Response

Recommended.

Brainstem auditory evoked response is recommended for use in the evaluation of TBI patients.

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 followup 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. Brainstem Auditory Evoked Response is not invasive has no adverse effects, is low cost, but appears to have utility to assess the hearing system and thus has evidence of diagnostic efficacy, and 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, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, BAER, ABR, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 75 articles in PubMed, 21 in Scopus, 2 in CINAHL, 5 in Cochrane Library, 11900 in Google Scholar, and 5 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 5 from other sources. Of the 6 articles considered for inclusion, 0 randomized trials and 6 systematic studies met the inclusion criteria.

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 [502]. It is commonly used to diagnose hearing loss [502].

Tympanometry

No Recommendation.

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

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, is low cost, but in the absence of quality evidence of diagnostic efficacy, there is no recommendation for evaluation 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 function tests, test, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, craniocerebral Injury, Craniocerebral Trauma; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 74 articles in PubMed, 7 in Scopus, 24 in CINAHL, 2 in Cochrane Library, 44 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 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 studies met the inclusion criteria.
Comments:	

Vestibular Function Testing

Vestibular function testing is used to quantify and assess the status of an individual's vestibular system workings [503]. Vestibular function testing has been used to help define the severity and possible outcomes of an individual's dizziness and balancing issues [503]. 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) [504].

Vestibular Function Testing

Recommended.

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

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. There are no studies showing testing is superior to a medical history or questionnaires. There are reports of vestibular dysfunction in TBI patients [168]. 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, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Vestibular function tests, test, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, craniocerebral Injury, Craniocerebral Trauma; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 74 articles in PubMed, 7 in Scopus, 24 in CINAHL, 2 in Cochrane Library, 44 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 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 studies met the inclusion criteria.

Balance Testing

Following a mild traumatic brain injury, up to 30% of patients report having balance disorders including, dizziness, impaired balance, and reduced coordination [505]. Typically, clinicians diagnose balance impairment following Traumatic Brain Injury using subjective measures. However, objective measures can be assessed using a computerized dynamic posturography platform [506].

Computerized Dynamic Platform Posturography

No Recommendation.

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

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There are no quality studies assessing Computerized Dynamic Platform Posturography for evaluation of TBI. Computerized Dynamic Platform Posturography is not invasive, has no adverse effects, is low cost, but without quality evidence of diagnostic efficacy, and there is no recommendation for evaluation 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: Computerized Dynamic Platform Posturography, Posturography, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 22 articles in PubMed, 9 in Scopus, 20 in CINAHL, 7 in Cochrane Library, 1 in Google Scholar, and 1 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 1 from CINAHL, 1 from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Of the 5 articles considered for inclusion, 2 randomized trials and 1 systematic studies met the inclusion criteria.

Electronystagmography or Videonystagmography

No Recommendation.

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

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – **Low**

Rationale:	There are no quality studies assessing electronystagmography or videonystagmography for evaluation of TBI patients. Electronystagmography and videonystagmography are not invasive, have no adverse effects, are low cost, but have no quality evidence of efficacy, and thus there is no recommendation for evaluation of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Electronystagmography, Videonystagmography, Traumatic brain injury, Closed Head Injury, Penetrating Head Injury, Concussion, Craniocerebral Injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 207 articles in PubMed, 4 in Scopus, 2 in CINAHL, 4 in Cochrane Library, 28000 in Google Scholar, and 0 from other sources. We considered for inclusion 3 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 1 randomized trials and 2 systematic studies met the inclusion criteria.

Rotary chair testing is used to diagnose vestibular impacts of traumatic brain injuries. Rotary chair testing examines vestibular and oculomotor functioning [508].

Rotary Chair Testing

Recommended.

Rotary chair testing is recommended for the evaluation of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**

Level of Confidence – **Low**

Indications:	TBI patients with vestibular problems needing further diagnostic evaluation
Benefits:	Secure a diagnosis and potentially improve treatment efficacy.
Harms:	Negligible.
Frequency/Dose/Duration:	Generally only assessed once.
Rationale:	There are few quality studies assessing Rotary Chair Testing for evaluation of vestibular impacts of TBI. Vestibular dysfunction is reportedly problematic in TBI patients [168]. Rotary Chair Testing is not invasive, has no adverse effects, is low cost, has evidence of diagnostic efficacy, and is recommended for diagnosis of vestibular impacts 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: Rotary Chair testing, traumatic brain injury; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy,

and efficiency. We found and reviewed 2 articles in PubMed, 0 in Scopus, 1 in CINAHL, 0 in Cochrane Library, 3,220 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 articles considered for inclusion, 1 Diagnostic study met the inclusion criteria.

ENG Studies for Balance

Recommended.

ENG studies for balance are recommended for use in the evaluation of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Indications:	TBI patients with balance problems needing further diagnostic evaluation
Benefits:	Secure a diagnosis and potentially improve treatment efficacy.
Harms:	Negligible.
Frequency/Dose/Duration:	Generally only assessed once.
Rationale:	There are no quality studies assessing ENG Studies for evaluation of balance or dizziness in TBI patients. However, ENG has proven helpful in the evaluation of patients with other disorders. ENG is not invasive, has no significant adverse effects, is low cost, has evidence of diagnostic accuracy for other disorders, and thus is recommended for evaluation of TBI patients with balance and dizziness problems.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Electronystagmography, balance, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Gold-standard, accurate, accuracy, precision, precise, diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 4 articles in PubMed, 10 in Scopus, 0 in CINAHL, 3 in Cochrane Library, 150 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Laboratory Testing

Injury severity and medications dictate testing in the TBI patient. 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 which may be present after acute injury signaling a pre- (chronic traumatic encephalopathy) CTE state and assisting in clinical treatment and guiding prognosis [510]. Also, since approximately 15-20% of MTBI cases involve hypopituitarism, endocrine tests are commonly required; in such cases, electrolytes should be closely monitored as concomitant syndrome of inappropriate antidiuretic hormone [511-515] and hypopituitarism are common [516].

Biomarkers

Biomarkers are under investigation as potentially predictive tools, particularly to supplement clinical assessment and neuroimaging tests [179, 180]. Biomarkers with some evidence of associations with TBI include autoantibodies against proteins, lipids, peptides, proteins, and RNA. Proteins studied include S-100 [181] [182] [183] [184] [185]. Reduced copeptin has been associated with TBI [186]. Galectin 3 [186] and occludin [186] has been associated with TBI. Problems with biomarker measurements include technical and instrumentation methods that require further development [180].

There are some data suggesting biomarkers may be associated with longer-term outcomes from TBI. While there is considerable evidence that biomarkers are associated with TBI, how measurement of these substances alters the management of TBI patients is unclear and thus there is **No Recommendation, Insufficient Evidence (I)** for or against biomarkers. Quality studies showing biomarkers impacting the management of patients are needed. Another potential use is to identify resolution of TBI [187], yet that too requires more sensitive methods and further investigation.

Lumbar Puncture

Lumbar puncture (LP) is performed to examine cerebrovascular fluid in cases of injury and disease for signs of hemorrhage [1, 517-521]. It is the most common test performed to evaluate signs of infection, thus in TBI patients 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.

Surgical Recommendations

Operative and Surgical Procedures

The TBI patient may require surgery particularly during the acute stage depending upon the individual injury mechanism and clinical presentation [588]. 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 TBI patients, 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 [589]
- 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) [590, 591]
- Nerve repair/reconstruction/release
- Orthopedic surgeries for fractures
- Rhizotomy for spasticity as well as intrathecal Baclofen (see Medication Recommendations)
- Soft tissue repairs
- Relief of vascular occlusions
- Ventricular shunting
- Ventriculostomy for ICP and obstructive hydrocephalus

There are no specific surgical recommendations as the requirements of the individual patient are wide-ranging and beyond the scope of this guideline.

Burr Holes, External Ventricular Drains, and Ventriculostomy

External ventricular drains (ventriculostomy) have been used in severe traumatic brain injury patients to reduce intracranial pressure rapidly [592]. This may be followed by permanent shunting [593]. These procedures are performed to attempt to improve cerebral blood flow, thus hopefully enhancing perfusion of the brain tissue and thus improving TBI prognosis [593-596]. Another type of ventriculostomy, percutaneous CT-controlled ventriculostomy (PCV), is a related technique with the main advantage of 50% faster completion than burr-holing, thus purportedly providing greater safety while monitoring and treating intercranial pressure [594, 595].

Craniectomy

Decompressive craniectomy is most commonly used for TBI and ischemic stroke as a third-tier therapy [592, 597-610]. It is performed to decrease intracranial pressure (ICP) by lowering the volume constraints on the cranial contents [599, 603, 607]. Complications related to decompressive craniectomy include infection, homeostatic reaction, hygroma, seizures, and bone resorption [607]. The procedure has been advocated to be performed early purportedly to confer a better prognosis [600, 607]. In Jelcic 2013, there was evidnce for improvement of executive functions after late craniectomy.

There is one high-quality RCT comparing decompressive craniectomy plus standard care to standard care alone [611, 612]. There also are 2 moderate-quality RCTs comparing different surgical techniques. The non-randomized studies have shown mixed results [592, 597-608].

The sole trial comparing craniectomy to non-surgical management has conflicting results, with clear short-term benefits including 28% lower ICU length of stay, 27% lower days of mechanical ventilation and 24% reduction in hospitalization days [611] [612]. However, the longer-term outcomes are not positive as shown by 70% vs. 51% unfavorable Extended Glasgow Outcome Scale Scores. Randomized controlled trials are investigating use of craniectomy for TBI patients and are tending to suggest only limited applicability to severe TBI patients refractory to medical management [613].

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: evacuation of hematoma, or subdural hematoma, or epidural hematoma, 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 1113 articles in PubMed, 91 in Scopus, 28 in CINAHL, 82 in Cochrane Library, 3730 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 2 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Lumbar drains for cerebrovascular fluid (CSF) leaks or CSF fistula, 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 102 articles in PubMed, 0 in Scopus, 5 in CINAHL, 0 in Cochrane Library, 2390 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: maxillofacial fracture surgery, bone, surgery, fracture, fractures, maxillofacial nerve repair, maxillofacial reconstruction, maxillofacial release; 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 209 articles in PubMed, 0 in Scopus, 0 in CINAHL, 3 in Cochrane Library, 10020 in Google Scholar, and 0 from other sources. We considered for

inclusion 4 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Vascular Occlusions Relief , Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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, 2 in Scopus, 0 in CINAHL, 2 in Cochrane Library, 3670 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Ventriculostomy for ICP and obstructive hydrocephalus, 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 2 articles in PubMed, 20 in Scopus, 7 in CINAHL, 1 in Cochrane Library, 391 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 articles considered for inclusion, 0 randomized trials and 1 systematic studies met the inclusion criteria.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Rhizotomy for spasticity, 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, 11 in Scopus, 0 in CINAHL, 0 in Cochrane Library, 2022 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 1 systematic studies met the inclusion criteria.

Orthopedic Surgery for Fractures

Orthopedic surgery involves surgery with the musculoskeletal system. Not many studies are found dealing with orthopedic surgery and traumatic brain injury. Most studies found deal with surgery with the brain itself or with the spine which are not relevant.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Orthopedic Surgery, Brain Injuries, Head Injuries Closed, Head Injuries Penetrating, Brain Concussion, Concussion, Craniocerebral Trauma, Traumatic Brain Injury, Intracranial Injury, 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 55 articles in PubMed, 76 in Scopus, 0 in CINAHL, 0 in Cochrane Library, 0 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria.

Soft Tissue Repairs

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: **soft, tissue, repair, traumatic, brain, injury, intracranial, closed, head, penetrating, concussion, 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 42 articles in PubMed, 0 in Scopus, 0 in CINAHL, 1 in Cochrane Library, 15700 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 15743 articles considered for inclusion, 0 randomized trials and 0 systematic studies met the inclusion criteria. Zero articles met the inclusion criteria.

Ventricular Shunting

Ventricular shunting is the process of surgically inserting a shunt into the head in order to drain fluid and to relieve pressure. This is done usually on patients who have hydrocephalus, which is the build-up of fluid in the brain. It is, per se, not a treatment for TBI.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: **Ventricular shunting OR Ventriculoperitoneal (VP) shunt OR VP Shunting AND Brain injuries, head injuries, closed, penetrating, brain concussion, concussion, craniocerenral trauma, traumatic brain, intracranial, injury, injuries,** 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, 19 in Scopus, 3 in CINAHL, 1 in Cochrane Library, 2570 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 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 trials and 0 systematic studies met the inclusion criteria.

Debridement

Debridement is the removal of damaged tissues or foreign objects. Surgical considerations for debridement surgery in traumatic brain injury patients is not a commonly used treatment, unless in cases of foreign object entrance to the brain.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Debridement, Brain Injuries, Head Injuries, Penetrating, Brain Concussion, Concussion, Craniocerebral Trauma, Traumatic Brain, Intracranial, Closed Head, Penetrating Head, Craniocerebral, Injury, Injuries, 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, 56 in Scopus, 0 in CINAHL, 1 in Cochrane Library, 6900 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria.

Decompression and Facial Nerve Decompression

Facial nerve decompression surgery has been used to treat facial nerve paralysis after temporal bone fractures [614], but there is no evidence that facial nerve decompression is used to treat TBI.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Surgical Decompression OR Facial Nerve Decompression, 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 168 articles in PubMed, 419 in Scopus, 46 in CINAHL, 3 in Cochrane Library, 4490 in Google Scholar, and zero from other sources. We considered for inclusion 1 from PubMed, 2 from Scopus, 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 trials and 2 systematic studies met the inclusion criteria.

Rapidly emerging innovative technologies for rehabilitation include robotics [615]. 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 [616-619].

Robotics

Recommended.

Robotics are recommended for use in the treatment of select TBI patients.
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

Frequency/Dose/Duration:	N/A
Indications for Discontinuation:	Falls, inability to tolerate, disinterest, disuse.
Rationale:	There are two moderate quality RCTs studies using robotics for treatment of TBI [620, 621]. One trial reported greater walking distance and no need for second therapists for training sessions with a robotic device compared with locomotor training [621]. Another trial reported mostly comparable efficacy with manually-assisted treadmill training [620]. There also are numerous successes of wheelchair-bound patients regaining the ability to walk [622-632] and there is one RCT in stroke patients [632]. Robotics 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 severe TBI patients.
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, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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, 12 in Scopus, 7 in CINAHL, 1 in Cochrane Library, 70 in Google Scholar, and zero from other sources. Zero articles met the inclusion criteria.

Nonoperative Treatment Recommendations

Intracranial Pressure Monitoring and Thresholds

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 TBI patients [522-526].

Intracranial Pressure Monitoring and Thresholds

Recommended.

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

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 severe TBI 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:	There are some quality studies assessing Intracranial Pressure Monitoring & Thresholds for monitoring and treatment of TBI. Studies consistently demonstrate correlations between intracranial pressure and clinical outcomes [522, 524-527]. 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 severe TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, Intracranial Pressure, Cerebral Perfusion Pressure, Monitoring thresholds ;diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 18 articles in PubMed, 13 in Scopus, 9 in CINAHL, 6 in Cochrane Library, 18500 in Google Scholar, and 0 from other sources. We considered for inclusion 4 from PubMed, 2 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 5 from Google Scholar, and 0 from other sources. Of the 11 articles considered for inclusion, 4 prognostic studies and 3 systematic studies met the inclusion criteria.

Oxygen Monitoring and Thresholds

Recommended.

Oxygen monitoring is recommended for use in the evaluation of TBI patients.

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 severe TBI 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:	There are quality studies assessing Brain Oxygen Monitoring and Thresholds for treatment and monitoring of TBI [529-540]. The Brain Oxygen Monitoring and Thresholds diagnostic test is invasive, has adverse effects, is high cost, but has evidence of clinical efficacy, and thus is selectively recommended for treatment of 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: brain, brain tissue, oxygen, monitoring, thresholds, traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 168 articles in PubMed, 105 in Scopus, 25 in CINAHL, 118 in Cochrane Library, 31,800 in Google Scholar, and 13 from other sources. We considered for inclusion 6 from PubMed, 2 from Scopus, 2 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 6 from other sources. Of the 17 articles considered for inclusion, 12 prognostic studies and 5 systematic studies met the inclusion criteria.

Osmotherapy, including: Mannitol, Hypertonic Saline, Lactate, Albumin

Increased intracranial pressure is associated with considerably worse mortality from TBI; thus, therapies to reduce intracranial pressure have been used for decades. Mannitol or mannite is a sugar alcohol that has the capability to cross the blood-brain barrier and used extensively in osmotherapy as a means of attempting to control elevated pressure following head trauma. Excessive use purportedly increases skull pressure and brain swelling and for this reason, mannitol has been recommended for patients with raised intracranial pressure or poor neurological status [541-549]. Hypertonic saline, sodium lactate solutions, lactated Ringer's solution, glycerol, crystalloids or albumin have also been used for reducing intracranial pressure from traumatic brain injury [550-554].

There also are many studies of resuscitation with hypertonic saline [80, 553, 555-558], dextran plus hypertonic saline [555, 557, 559, 560], and normal saline [556, 557, 559-562] for resuscitation including during transport and/or in ICUs. There are studies of lactated Ringer's solution for use in resuscitation [80, 553, 555, 558]. There are a few studies of albumin for use in resuscitation [561, 563].

Mannitol for Intracranial Pressure

Recommended.

Mannitol is recommended for reducing intracranial pressure in TBI patients.

Strength of Evidence –Acute, Severe- **Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Indications:	For decreasing brain swelling in acute, severe TBI patients, used as an osmotic diuretic
Benefits:	Reduced brain swelling post TBI
Harms:	Hypotension, acidosis, drug allergy
Frequency/Dose/Duration:	Administration adjusted to pressure measures from a direct pressure device. Common targets also include increasing serum osmolarity to an initial target of 300-320mOsm/L or increase the serum sodium to 145 -150mmol/L.
Indications for Discontinuation:	Hypotension, pulmonary congestion, fluid and electrolyte imbalance, acidosis, electrolyte loss, dryness of mouth, thirst, marked diuresis, urinary retention, edema, headache, blurred vision.
Rationale:	Nearly all quality evidence regarding mannitol used active controls. There is only one placebo controlled trial of normal saline that assessed early, in-field administration of mannitol [564]. One moderate-quality trial found much worse mortality for those treated with pentobarbital compared with mannitol [542]. Most of the remaining quality evidence compared mannitol with hypertonic saline and found no significant differences in outcomes [565, 566], thus showing comparable efficacy between mannitol and hypertonic saline. Mannitol is invasive, has significant adverse effects and is costly over time, but with strong evidence of mortality from increased intracranial pressure, it is one of the recommended options for treatment. There is no evidence to recommend hypertonic saline over mannitol, thus hypertonic saline is similarly recommended (see below).
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: mannitol or mannite or manna sugar; brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or

penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 194 articles in PubMed, 405 in Scopus, 40 in CINAHL, 4 in Cochrane Library and 0 in other sources. We considered for inclusion 17 from PubMed, 0 from Scopus, CINAHL, Cochrane Library and other sources. Of the 17 articles considered for inclusion, 8 randomized trials and 8 systematic studies met the inclusion criteria. There are 7 moderate-quality RCTs incorporated into this analysis. There are 6 low-quality RCTs. There are 8 systematic reviews.

Hypertonic Saline for Intracranial Pressure

Recommended.

Hypertonic saline is recommended for reducing intracranial pressure in TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence **– Moderate**

Indications:	Severe TBI with intracranial pressure >20mmHg for more than 5 minutes.
Frequency/Dose/Duration:	100mL of 7.5% Saline over 5 min by central venous catheter [568]; [566]. Administration adjusted to pressure measures from a direct pressure device. Common targets also include increasing serum osmolarity to an initial target of 300-320mOsm/L or increase the serum sodium to 145-150mmol/L.
Indications for Discontinuation:	Fever and other adverse effects
Benefits:	Reduces ICP but maintains cerebral perfusion
Harms:	Fever
Rationale:	There are a few moderate quality trials comparing hypertonic saline with other solutions for managing increased intracranial pressure. Two trials found comparable results with mannitol [565, 566]. One trial suggested no difference between hypertonic saline and equimolar sodium bicarbonate [569]. Hypertonic saline is invasive, has significant adverse effects and is costly for administrations over time, but with strong evidence of mortality from increased intracranial pressure, it is one of the recommended options for treatment. There is no evidence to recommend hypertonic saline over mannitol, thus mannitol is similarly recommended (see above).
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: mannitol or mannite or manna sugar; brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 194 articles in PubMed, 405 in Scopus, 40 in CINAHL, 4 in Cochrane Library and 0 in other sources. We considered for inclusion 17 from PubMed, 0 from Scopus, CINAHL, Cochrane Library

and other sources. Of the 17 articles considered for inclusion, 8 randomized trials and 8 systematic studies met the inclusion criteria.

Ringers Lactate for Intracranial Pressure

No Recommendation.

There is no recommendation for ringers or lactated solutions for treatment of intracranial pressure.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Benefits:	Reduction in ICP
Harms:	Lactate acidosis
Rationale:	Relatively few studies have assessed lactated solutions for treatment of TBI. One trial reported lactate produced greater reductions in intracranial pressure compared with mannitol [551], while another found more treatment failures with mannitol [551]. One randomized controlled trial concluded that a 48 hour half-molar sodium lactate infusion aids in reducing the number of elevated intracranial pressure episodes for those experiencing severe traumatic brain injury, while decreasing chloride and fluid balances [550] [551]. One trial suggests hyperosmolar sodium lactate is superior to mannitol [551]. Another trial suggested One randomized prospective trial established that lactated Ringer's solution in combination with hypertonic saline assisted in controlling rising intracranial pressure following a traumatic brain injury [552]. Another study found that dextran 70 and sodium chloride solution serves to more effectively raise blood pressure and improve survival than lactated Ringer's solution when administered before hospitalization[553].
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: mannitol or mannite or manna sugar; brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 194 articles in PubMed, 405 in Scopus, 40 in CINAHL, 4 in Cochrane Library and 0 in other sources. We considered for inclusion 17 from PubMed, 0 from Scopus, CINAHL, Cochrane Library and other sources. Of the 17 articles considered for inclusion, 8 randomized trials and 8 systematic studies met the inclusion criteria. There are 17 moderate-quality RCTs incorporated into this analysis.

Hyperbaric Oxygen Therapy (HBO or HBOT)

Hyperbaric oxygen has been used as a treatment for TBI [385, 571-580].

Hyperbaric Oxygen Therapy (HBO or HBOT)

Sometimes Recommended.

Hyperbaric oxygen therapy is sometimes recommended for the treatment of TBI patients.

Strength of Evidence – *Mild TBI:* **Moderately Not Recommended, Evidence (B)**

Moderate TBI: **No Recommendation, Insufficient Evidence (I)**
Severe TBI: **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 [581]. Not recommended in mild TBI and no recommendation in moderate TBI.
Benefits:	Improved outcomes, earlier improvements in Glasgow Coma Score. Reduced mortality in one study with randomization within 24 hrs. of severe TBI [582]
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 [581].
Indications for Discontinuation:	Brain dead, able to consistently repond to commands [581].
Rationale:	The top three quality studies all showed negative effects of HBO for treatment of mild TBI/post-concussive symptoms [583] [584] [585]. Three moderate quality trials among severe TBI patients found significant improvements in mortality in the HBO group [581], 10; [586, 587]. 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. There is quality evidence of lack of efficacy for treatment of mild TBI and so it is not recommended for that indication. There is no quality evidence and thus 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 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 100 articles in PubMed, 1062 in Scopus, 14 in CINAHL, 17 in Cochrane Library, 1790 in Google Scholar, and 0 from other sources. We considered for inclusion 13 from PubMed, 1 from Scopus, 0 from CINAHL, Cochrane Library, Google Scholar, and 0 from other sources. Of the 13 articles considered for inclusion, 10 randomized trials and 3 systematic studies met the inclusion criteria.

Nutritional Support

Nutritional Support in TBI Patients

Recommended.

Patients with TBI commonly develop nutritional deficits such as hypercatabolism, hypermetabolism, and glucose intolerance [633]. Most severe TBI patients experience altered/delayed gastric emptying at least one week post injury and some experience this for considerably longer periods of time which may affect their ability to tolerate enteral feedings.

Nutritional support is usually not required in TBI patients other than select, severe TBI patients. Those who are unable to eat or adequately protect the airway need nutritional support. If the GI tract is functional, then the preferred treatment is a gastric or other enteric feeding tube. Using the functioning GI tract is far preferable to total parenteral nutrition as the GI tract helps to maintain better nutritional status as well as improving serum electrolyte control [634] showed patients who initially had rapid or normal gastric emptying tolerated full-strength full-rate feedings significantly earlier compared with those who experienced delayed gastric emptying.

Total parenteral nutrition is needed if there is an estimate beyond several days for use of the GI tract due to either: [170] an inability to use the GI tract (e.g., injured abdomen, abdominal surgery, prior disease) or (2) delayed gastric emptying sufficiently severe to preclude adequate nutrition using an enteric feeding tube.

There are no specific nutritional support recommendations as the requirements of the individual patient are wide-ranging and beyond the scope of this guideline.

Acute Therapeutic Procedures

Prophylactic hyperventilation therapy has been used to improve intracranial pressure (ICP) and neurologic functioning. Intracranial pressure is increased in 50% to 75% of patients with severe head trauma [635, 636] and the duration of increased intracranial pressure >20 mm Hg has been found to be strongly correlated with worse outcomes [637].

Hyperventilation

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 [638, 639].
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. As this treatment has long been in place, this somewhat impairs the size and quality of the evidence base. 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, has empirical evidence of short term efficacy for treatment of TBI and thus 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 67 articles in PubMed, 268 in Scopus, 24 in CINAHL, 2 in Cochrane Library, 7800 in Google Scholar, and 0 from other sources. We considered for inclusion 12 from PubMed, 0 from Scopus, CINAHL, Cochrane Library, Google Scholar, and 0 from other sources. Of the 12 articles considered for inclusion, 5 randomized trials and 5 systematic studies met the inclusion criteria.

Induced Hypothermia

Not Recommended.

Induced hypothermia is not recommended for the treatment of TBI patients.

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 [651-653, 655-661, 664, 665, 667, 669, 670, 673-675, 677-679].While there are some lower quality studies that suggested efficacy, all of the 3 highest quality studies show a lack of efficacy [651, 652, 655] and two were terminated early because of futility. There is no evidence of efficacy for prophylactic treatment. Induced Hypothermia is not invasive, has multiple adverse effects, is moderate cost, has quality evidence of a lack of utility in treatment of TBI and thus 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: hypothermia, induced, induced hypothermia, therapeutic hypothermia, protective hypothermia, targeted temperature 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 543 articles in PubMed, 1,904 in Scopus, 60 in CINAHL, 166 in Cochrane Library, 3,220 in Google Scholar, and 37 from other sources. We considered for inclusion 8 from PubMed, 2 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 37 from other sources. Of the 47 articles considered for inclusion, 29 randomized trials and 16 systematic studies met the inclusion criteria.

Swallow Studies

Swallowing impairment (dysphagia) is common in some severe TBI patients due to prolonged intubation or tracheostomy, the traumatic injury itself, medications or weakened swallowing muscles due to lack of use [680-682]. 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 ranging from the bedside clinical assessment, the modified Evans Blue-Dye Test (MEBDT), to instrumental evaluations like barium swallow, modified barium swallow (MBS) fiberoptic endoscopy (FEES), fiberoptic endoscopic evaluation with sensory testing (FEEST) and a videoflouroscopic study which adds 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.

Family Visits

Family visits have been used to attempt to induce increased and earlier arousal from coma [683, 684]. Many individuals with traumatic brain injury (TBI) experience a longer period of sensory deprivation [683]. This is in part due to the increased hospitalization, immobilization, and isolation. To help recovery structured family visits are used to increase sensory stimulation including; visual, tactile, gustatory, tactile, and equilibrium stimuli [684].

Family Visits

Recommended.

Family visits are recommended for the treatment of comatose TBI patients.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Low

Indications:	Comatose patients.
Benefits:	Potential for increased and earlier arousal from coma.
Harms:	None
Rationale:	There are two moderate quality studies suggesting increased family visits may result in either increased arousal or earlier arousal [683, 684]. Family visits are not invasive, have negligible adverse effects, are low cost, have evidence of efficacy and are thus recommended for comatose patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Family Visit; 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, 56 in Scopus, 3 in CINAHL, 82 in Cochrane Library, 310 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 2 randomized trials and 0 systematic studies met the inclusion criteria.

Multimodal and Unimodal Coma Stimulation

Multimodal coma stimulation has been used to treat comatose TBI patients [685-688].

Multimodal and Unimodal Coma Stimulation

Recommended.

Multimodal and unimodal coma stimulation are recommended for the treatment of comatose TBI patients.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Low

Indications:	Comatose TBI patients. The highest quality study included those with Glasgow Coma Score <8 [685]
Benefits:	Improved arousal, lessening of coma severity
Harms:	Negligible
Frequency/Dose/Duration:	5 times/day, 20 min./session. 2 hrs between session. Stimulations consisted of visual, auditory, tactile, olfactory and gustatory. Two trials either utilized a family member talking to the patient [689] or a familiar voice telling stories in common with the patient [690].
Rationale:	There is one moderate quality trial suggesting multimodal coma stimulation results in improvement in Glasgow Coma Score [685]. Two trials of familiar voices suggest successful improvements [689, 690]. Uni-or multimodal coma stimulation is not invasive, has no adverse effects, may be low (familiar voice) to moderate to high cost in aggregate (multimodal), has evidence of efficacy and thus is recommended for comatose TBI patients.
Evidence:	Multimodal Coma stimulation– A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: 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 4 articles in PubMed, 15 in Scopus, 6 in CINAHL, 6 in Cochrane Library, 1410 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 3 from other sources. Of the 5 articles considered for inclusion, 1 randomized trials and 0 systematic studies met the inclusion criteria.

Occupational Therapy

Occupational therapy is broadly defined as patient- or client-centered interventions aiming to return individuals to his/her everyday activities and occupation. Most occupational therapists are trained to recognize cognitive, psychological, sensory-perceptual, and physical issues that may influence the treatment and recovery of patients with TBI. Occupational therapy surrounding cognitive rehabilitation is traditionally broken into two approaches [691]. The remedial approach focuses on the restoration of cognitive functions, while the adaptive approach focuses on overcoming the limitations caused by a traumatic brain injury [78]. Similar to physical therapy, there is little quality evidence to support occupational therapy as an aggregate intervention.

Occupational Therapy

Recommended.

Occupational therapy is recommended for moderate to severe TBI patients with functional deficits, especially those that impair employability.

Allied Health Interventions

Strength of Evidence – Recommended, Insufficient Evidence (I)
Level of Confidence – Low

Indications:	For moderate to severe TBI patients with functional deficits, especially those that impair employability
Frequency/Dose/Duration:	Regimens varied widely. They included: 16 weeks of 15 hours per week of intensive OT [692]; 1.5-2.5hr/day for 60 days [166];
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve.
Benefits:	Self perceived quality of life, faster recovery and shortened hospitalization time which decreases costs associated with TBI.
Harms:	Negligible
Rationale:	There are 5 moderate quality studies involving the use of OT [166, 692-694] and [695]. Cicerone suggest a comprehensive approach is best but all studies show either modest benefits or no differences. Details of the studies are limited. Occupational therapy is not invasive, has low adverse effects, is high cost, but some modalities and treatments are likely effective, thus occupational therapy is recommended. Better evidence-based guidance is able to be found from structured trials of specific interventions.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Occupational therapy, 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 29 articles in PubMed, 1011 in Scopus, 17 in CINAHL, 1 in Cochrane Library, 5750 in Google Scholar, and 0 from other sources. We considered for inclusion 5 from PubMed, 1 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 5 randomized trials and 2 systematic studies met the inclusion criteria.

Physical Therapy

The term “physical therapy” is used here in the generic sense to include physical medicine and therapeutic and rehabilitative evaluations and procedures. Physical therapists are major health care providers who render many of these services through multiple, specific interventions (e.g., exercise, ultrasound, manipulation. The majority, if not all, of these interventions are also employed by other health care practitioners. However, there are a few RCTs of “physical therapy.” The studies in this section include numerous interventions and lack structuring of treatments within the arms of these trials. Thus, there are no strong conclusions that may be drawn from this body of evidence with respect to the value of individual modalities and comparisons between generic treatment programs are weak. These studies of “physical therapy” are reviewed here for completeness.

Physical Therapy

Recommended.

Physical therapy is recommended for use in the treatment of chronic severe or moderately severe TBI patients with functional physical deficits.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	For subacute, chronic severe or moderately severe TBI patients with functional physical deficits, such as balance, strength or coordination.
Frequency/Dose/Duration:	Trials have used daily to weekly visits for 8 weeks [166, 696]. One trial used twice daily visits for 2 weeks [697].
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve.
Benefits:	Quicker recovery and return to work with accelerated independence.
Harms:	Negligible
Rationale:	There are 6 moderate quality studies involving PT [166, 696-699, 700]The trials are generally not well described, used multiple interventions and were not well structured. Most suggested improvements with higher intensity of therapy. In one [701] there was no evidence of efficacy. In [698] there was a quicker return to work with intensive therapy, but at one year the functional outcomes were similar between groups and also in [699]there was seen a faster resumed independence and accelerated time to discharge from hospitalization. Physical therapy is not invasive, has low adverse effects, is high cost, but some modalities and treatments are likely effective, thus physical therapy is recommended. Better evidence-based guidance is able to be found from structured trials of specific interventions.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, physical therapy, physical rehabilitation, physical rehab; 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 428 articles in PubMed, 1500 in Scopus, 39 in CINAHL, 228 in Cochrane Library, 100 in Google

Scholar, and 2 from other sources. We considered for inclusion 8 from PubMed, 3 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 2 from other sources. Of the 14 articles considered for inclusion, 7 randomized trials and 4 systematic studies met the inclusion criteria.

Exercise

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: **Exercise Therapy, Exercise, Circuit-Based 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 86 articles in PubMed, 619 in Google Scholar, and 0 from other sources. We considered for inclusion 7 from PubMed, 2 from Google Scholar, and 0 from other sources. Of the 9 articles considered for inclusion, 6 randomized trials and 0 systematic studies met the inclusion criteria.

Strengthening Exercises

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	For subacute, chronic, postoperative, moderate and severe TBI patients.
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.
Benefits:	Improved physical fitness, mood, self esteem and motor performance.
Harms:	Negligible
Rationale:	There are no quality trials including primarily strengthening exercises. Strengthening exercises are not invasive, have low adverse effects, are relatively low cost depending on supervision requirements and duration, 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: Strengthening, exercises, traumatic, brain, intracranial, closed, head, penetrating, craniocerebral, injury, trauma, concussion; 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, 1 in Scopus, 2 in CINAHL, 1 in Cochrane Library, 1150 in Google Scholar, and 0 from

other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1157 articles considered for inclusion, 0 randomized trials and 1 systematic studies met the inclusion criteria.

Stretching and flexibility exercises improve range of motion. When there is a poor range of motion, function can be significantly, adversely affected.

Stretching and Flexibility Exercises

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	For subacute, chronic, postoperative, moderate and severe TBI patients.
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.
Benefits:	Improved physical fitness, mood, self esteem and motor performance.
Harms:	Negligible
Rationale:	There are no studies involving primarily stretching and flexibility. There are no quality trials including primarily stretching and flexibility exercises. These exercises are not invasive, have low adverse effects, are low to moderate cost depending on supervision requirements and duration, 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: stretch, flexibility, stretching and flexibility, exercise, yoga, 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 91 articles in PubMed, 0 in Scopus, 5 in CINAHL, 0 in Cochrane Library, 12000 in Google Scholar, and 2 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 2 from other sources. Of the 2 articles considered for inclusion, zero randomized trials and 2 systematic studies met the inclusion criteria.

Relaxation exercises are activities that may help reduce anxiety, stress, anger, and pain. [118, 702] Group discussions may also be included in relaxation exercises. Relaxation is a broad topic that has many different types including physical, mental, and emotional techniques.

Relaxation Exercises, Group Discussions

No Recommendation.

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

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are 2 moderate quality studies involving relaxation. In [703], Qignong somewhat improved mood and self esteem and in [704], 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, are low cost and 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: Relaxation exercises, Group Discussion, Traumatic brain injury, Intracranial injury, Closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma, closed head trauma, penetrating head trauma, penetrating craniocerebral, trauma, population groups, relaxation, group therapy; 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 articles in PubMed, 0 in Scopus, 5 in CINAHL, 71 in Cochrane Library, 19800 in Google Scholar, and 1 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 1 from Cochrane Library, 1 from Google Scholar, and 2 from other sources. Of the 4 articles considered for inclusion, 2 randomized trials and 0 systematic studies met the inclusion criteria.

Aerobic Exercise

Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Indications:	For subacute, chronic, postoperative, moderate and severe TBI patients.
Frequency/Dose/Duration:	Generally prescribed on at least a daily basis. 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.
Benefits:	Improved physical fitness, mood, self esteem and motor performance.
Harms:	Negligible
Rationale:	There are 4 moderate quality studies involving aerobic exercise [703, 704, 707, 708]. One trial found improvements in cardiovascular fitness, but no psychological or functional change [704]. One trial found benefits from aquatic treatment [708]. There are no sizable trials including primarily aerobic exercises. Aerobic exercises are not invasive, have low adverse effects, are low to high cost depending on supervision requirements and duration, 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: Aerobic, exercise, exercising, 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 19 articles in PubMed, 115 in Scopus, 7 in CINAHL, 45 in Cochrane Library, 2,570 in Google Scholar, and 0 from other sources. We considered for inclusion 3 from PubMed, 1 from Scopus, 0 from CINAHL, 1 from Cochrane Library, 6 from Google Scholar, and 0 from other sources. Of the 11 articles considered for inclusion, 5 randomized trials and 6 systematic studies met the inclusion criteria.

Aquatic Therapy for Select TBI Patients

Recommended.

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

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Moderate

Indications:	Patient's 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.
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.
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 severe TBI patients.
Harms:	May aggravate pain in a minority.
Rationale:	There is one moderate quality study involving aquatic aerobic exercise [708] that suggested 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: Aerobic, exercise, exercising, 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 19 articles in PubMed, 115 in Scopus, 7 in CINAHL, 45 in Cochrane Library, 2,570 in Google Scholar, and 0 from other sources. We considered for inclusion 3 from PubMed, 1 from Scopus, 0 from CINAHL, 1 from Cochrane Library, 6 from Google Scholar, and 0 from other sources. Of the 11 articles considered for inclusion, 5 randomized trials and 6 systematic studies met the inclusion criteria.

Activity Modification

Rest is often recommended because of a concern for reinjury during recovery from concussion [709-711]

Rest

Not Recommended.

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

Strength of Evidence – **Not Recommended, Evidence (C)**
Level of Confidence – **High**

Rationale:	There are quality studies assessing Rest for treatment of TBI. 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, resting, 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 233 articles in PubMed, 467 in Scopus, 15 in CINAHL, 2 in Cochrane Library, 49800 in Google Scholar, and 0 from other sources. We considered for inclusion 8 from PubMed, 0 from Scopus, CINAHL, Cochrane Library, Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 3 randomized trials and 3 systematic studies met the inclusion criteria.

Body Weight Support Treadmill Training for TBI Patients

Recommended.

Body weight support treadmill training is recommended for use in the treatment of TBI patients 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 2 comparative trials used widely differing regimens, i.e., 15min 2x/wk [713] and 45 min, 3x/wk [620].
Indications for Discontinuation:	Ability to walk with a walker, or to walk unassisted.
Rationale:	There are no sham or placebo-controlled trails. There are a few quality comparative studies assessing Body Weight Support Treadmill Training for treatment of TBI [713] [620], 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 TBI patients.

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 training, body-weight-supported treadmill training, body weight supported treadmill training, BWSTT; 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, 14 in Scopus, 1 in CINAHL, 10 in Cochrane Library, 329 in Google Scholar, and 1 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 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 1 systematic study met the inclusion criteria.

Constraint-Induced Movement Therapy (CI) for TBI Patients

Recommended.

Constraint-induced movement therapy is recommended for use in the treatment of severe TBI patients 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 [715]. Frequencies of an ongoing programunclear, 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:	There is one moderate-quality study assessing Constraint-Induced Movement Therapy (CIMT) for treatment of TBI. CIMT is not invasive, has no adverse effects, is moderate to high cost in agggregate, 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: Activity Modification, Constraint-induced movement therapy, CI, CIMT, Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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, 79 in Scopus, 4 in CINAHL, 18 in Cochrane Library, 897 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from

PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 3 articles considered for inclusion, 1 randomized trial and 0 systematic studies met the inclusion criteria.

Whole Body Vibration (WBV) for TBI Patients

No Recommendation.

There is no recommendation for or against the use of whole body vibration in the treatment of TBI patients.

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 so 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, 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 zero articles in PubMed, 205 in Scopus, zero in CINAHL, zero in Cochrane Library, 60 in Google Scholar, and zero from other sources. **Zero** articles met the inclusion criteria.

Specific motor stimulation has been used to treat hand impairments from stroke or TBI [719].

Specific Motor Stimulation

Recommended.

Specific motor stimulation is recommended for use in the treatment of moderate to severe TBI patients 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 [719].
Benefits:	Improved functional rehabilitation of an extremity
Harms:	Negligible
Frequency/Dose/Duration:	One hour session daily, 5 days/wk for 6 weeks.
Rationale:	There is one moderate quality trial suggesting specific motor stimulation is effective for rehabilitation of patients, however, 90% of the patients were stroke patients [719]. Specific motor stimulation is not invasive, has low adverse effects, is high cost in aggregate, and

	while some evidence suggests it may be effective, the population was not primarily TBI, thus it is recommended by consensus (I).
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: 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, 2742 in Scopus, 14 in CINAHL, 2 in Cochrane Library, 21500 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Systematic Instruction

Recommended.

Systematic instruction is recommended for the treatment of TBI patients 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
Frequency/Dose/Duration:	N/A
Rationale:	There is one moderate quality trial suggesting systematic instruction is more effective than trial-and-error learning for rehabilitation of TBI patients [720]. 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 TBI patients with moderate to severe cognitive impairments.
Evidence:	**Systematic Instruction**– A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: **Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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, 33 in Scopus, 0 in CINAHL, 92 in Cochrane Library, 22300 in Google Scholar, and 1 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 1 from other sources. Of the 1 articles considered for inclusion, 1 randomized trials and 0 systematic studies met the inclusion criteria.

Television-Assisted Rehabilitation

Recommended.

Television-assisted rehabilitation is recommended for use in the treatment of TBI patients.

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 [722].
Benefits:	Improved task completion. May be usable to remind to complete exercises or cognitive exercises.
Harms:	Negligible
Frequency/Dose/Duration:	N/A
Rationale:	There is one moderate quality trial of television-assisted rehabilitation for treatment of acquired brain injury patients that suggested some efficacy [722]. 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 TBI patients [722].
Evidence:	**Television Assisted Rehabilitation** – 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**; **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 1 articles in PubMed, 3 in Scopus, 2 in CINAHL, 0 in Cochrane Library, 11 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 1 articles considered for inclusion, 1 randomized trials and 1 systematic studies met the inclusion criteria.

Action Sequences

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:	Severe TBI patients 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 [724].
Rationale:	There is one moderate quality RCT [724] and one low quality trial [725]. The sole quality study suggests. 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 TBI patients.
Evidence:	Action Sequences– A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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, 76 in Scopus, 0 in CINAHL, 57 in Cochrane Library, 30400 in Google Scholar, and 1 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Of the 3 articles considered for inclusion, 1 randomized trials and 0 systematic studies met the inclusion criteria.

Cognitive Behavioral Therapies

Recommended.

Behavioral and Psychological Interventions

Cognitive behavioral therapies are recommended for use in the treatment of TBI patients with cognitive deficits.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – **Low**

Indications:	Moderate to severe TBI with cognitive deficits. Rare mild TBI patients with ongoing and significant symptoms may be candidates.
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:	Sufficient resolution, lack of progression, lack of compliance.
Rationale:	There are quality studies assessing Cognitive Behavioral Therapies for treatment of TBI, most of which suggest some efficacy, although there are some conflicts between the studies. Cognitive Behavioral Therapy is not invasive, has no adverse effects, is low cost, and has some evidence of efficacy and is thus recommended for treatment of select TBI patients.
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**;** 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 74 articles in PubMed, 371 in Scopus, 7 in CINAHL, 7 in Cochrane Library, 1800 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 2 from CINAHL, 1 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 5 randomized trials and 1 systematic studies met the inclusion criteria.

Cognitive-Motor Dual-Tasking

Recommended.

Cognitive-motor dual-tasking is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, 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 [741], but not cognitive-motor. There is one low quality study suggesting a trend towards improvement [740]. 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-Tasking; 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, 18 in Scopus, 1 in CINAHL, 0 in Cochrane Library, 87 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 1 articles considered for inclusion, 1 randomized trials and 0 systematic studies met the inclusion criteria.

Attention Regulation Training

Recommended.

Attention regularion training is recommended for use in the treatment of TBI patients.
Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – **Low**

Indications:	Moderate to severe TBI patients with indications of impaired attention, as well as problems with dual-tasking. [741] There may be select patients with ongoing symptoms from mild TBI who may be candidates.
Benefits:	Improvements in sustained attention and focus.
Harms:	Negligible
Frequency/Dose/Duration:	One regimen was 4x1hr individual training sessions/wk for 6 wks for up to 24 hours of training.
Indications for Discontinuation:	Sufficient recovery, ability to dual task, plateau, non-compliance with home exercises.
Rationale:	There are a few quality studies for the use of attention regulation training to treat TBI patients, and they mostly suggest efficacy, although the studies are heterogenous and not comparable [741] [742] [743]. Attention regulation training is not invasive, has no adverse effects, is low to moderate cost in aggregate and with

evidence suggesting efficacy is recommended for treatment of TBI patients.

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, 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 13 articles in PubMed, 4 in Scopus, 2 in CINAHL, 2 in Cochrane Library, 29,611 in Google Scholar, and 4 from other sources. We considered for inclusion 0 from PubMed, 5 from Scopus, 0 from CINAHL, 2 from Cochrane Library, 2 from Google Scholar, and 4 from other sources. Of the 7 articles considered for inclusion, 5 randomized trials and 2 systematic studies met the inclusion criteria.

Motivational Interviewing

Recommended.

Motivational interviewing is recommended for use in the treatment of patients with anxiety or depressive symptoms after TBI.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Indications: TBI 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 included: Four 20-minute sessions (Zatzick 2014), 10 weekly 2-hour sessions [745], to one session at 1, 2, 3, 5, 7, and 9 months post initial treatment (Bombardier 2009, Bell 2005).

Rationale: There are multiple moderate quality trials evaluating the usage of motivational interviewing for patients with TBI. Multiple moderate quality trials suggested motivational interviewing was successful in reducing symptoms of anxiety and depression (Ponsford 2016, Hsieh 2012, Bombardier 2009), with two utilizing cognitive behavioral therapy (Ponsford 2016, Hsieh 2012). However, one trial had baseline differences in groups concerning for potential randomization failure (Ponsford 2016). One moderate quality study suggested motivation interviewing can improve overall function (Bell 2005). Three moderate quality studies evaluated the usage of motivation interviewing for the treatment of alcohol consumption problems (Zatzick 2014, Tweedly 2012, Ponsford 2012). Two studies suggest efficacy (Zatzick 2014, Tweedly 2012) but one suggests readiness to change influences the effectiveness of treatment (Ponsford 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 so is recommended

	for selective treatment of TBI patients with anxiety or depressive symptoms and/or alcohol consumption problems after TBI.
Evidence:	A comprehensive literature search was conducted using PubMed without date limits using the following terms: motivational interviewing; brain injuries, closed head injuries, penetrating head injuries, brain concussion, concussion, craniocerebral trauma, traumatic brain, intracranial, closed head, penetrating head, craniocerebral, injury, injuries; 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 and 6 from other sources. We considered for inclusion 3 from PubMed and 6 from other sources. Of the 9 articles considered for inclusion, 9 randomized trials and 0 systematic studies met the inclusion criteria.

Emotional Training

Recommended.

Emotional training is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Indications:	TBI 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 [747]. The sole quality study included only those more than one year after TBI, however earlier treatment may be selectively appropriate. Mild TBI patients are not expected to need emotional training due to the TBI [153], 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 2015), 1-hour sessions per week for 16-20 weeks (Westerhof-Evers 2017), 1-hour sessions, 3 times per week for 2-3 weeks (Radice-Neumann 2009), and 8 two hour sessions given over 4 days (Tornås 2016a).
Rationale:	Multiple moderate quality trials (Tornås 2016a, Tornås 2016b, Westerhof-Evers 2017, Radice-Neumann 2009) evaluate the usage of emotional training in TBI patients. The multiple moderate quality studies suggested emotional training was successful in improving facial recognition and emotional processing (Tornås 2016a, Tornås 2016b, Westerhof-Evers 2017, Radice-Neumann 2009), however one study contained baseline differences in time from injury (Tornås 2016b). Emotional Training is not invasive, has negligible adverse effects, is moderate cost in aggregate, has some potential evidence of effectiveness and so is recommended for selective treatment of severe TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed without date limits using the following terms: emotional training,

emotion training; brain injuries, closed head injuries, penetrating head injuries, brain concussion, concussion, craniocerebral trauma, traumatic brain, intracranial, closed head, penetrating head, craniocerebral, injury, injuries; 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 and 2 from other sources. We considered for inclusion 3 from PubMed and 2 from other sources. Of the 5 articles considered for inclusion, 5 randomized trials and 0 systematic studies met the inclusion criteria.

Goal Setting

Recommended.

Goal setting is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale: Two moderate quality trials both have small sample sizes, underpowering and poor reporting of results [748, 749]. Yet re-learning goal setting and attainment are important tasks. Some data suggest efficacy [753-755]. These approaches to goal setting are not invasive, have no adverse effects, are moderate to high cost in aggregate, so therefore 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, 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 114 articles in PubMed. We considered for inclusion 11 from PubMed and 1 from Google Scholar. Of the 12 articles considered for inclusion, 7 randomized trials and 5 systematic studies met the inclusion criteria.

Education Programs

Recommended.

Education programs are recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There are no quality studies assessing education programs for treatment of TBI. Education programs are not invasive, have no adverse effects, are low cost when education is incorporated in other rehabilitation programs, has 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: Educational program**;** 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 35 articles in PubMed, 240 in Scopus, 6 in CINAHL, 13 in Cochrane Library, 50 in Google Scholar, and zero from other sources. Zero articles met the inclusion criteria.

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

No Recommendation.

There is no recommendation for or against the use of neuroplasticity in the treatment of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There are no quality studies assessing Neuroplasticity for treatment of TBI. Neuroplasticity is not invasive has no adverse effects, is low cost, but in the absence of quality evidence of 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: Neuroplasticity, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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, 58 in Scopus, 1 in CINAHL, zero in Cochrane Library, 210 in Google Scholar, and zero from other sources. Zero articles met the inclusion criteria.

A social peer mentoring program has been included in the treatment of TBI patients [756] to address social isolation that has been reported in this population [757-760]

Peer Mentoring Program

No Recommendation.

There is no recommendation for or against the use of a peer mentoring program in the treatment of TBI patients.

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 [756]. Peer-Mentoring is not invasive, have no adverse effects, are moderate to high cost in aggregate and 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: mentoring, mentored, traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; 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 Scopus, 0 in CINAHL, 0 in Cochrane Library, 0 in Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 3 randomized trials and 1 systematic study met the inclusion criteria

Video feedback on task performance has been used for treatment of TBI patients [762, 763]. Decreased self-awareness is suggested to occur due to a number of neuroanatomical as well as cognitive impairments [764, 765].

Video Feedback on Task Performance

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:	TBI patients with task performance problems after severe TBI. The quality trial used meal preparation as the outcome [762, 763], 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 [762, 763],
Rationale:	One moderate quality trial with two reports suggested a combination of video feedback with verbal was superior to either approach alone [762, 763], 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 so is recommended for selective treatment of severe TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: feedback intervention, traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; 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 32 articles in PubMed, 10 in Scopus, 5 in CINAHL, 4 in Cochrane Library, 90 in Google Scholar, and 3 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, CINAHL, Cochrane Library, and from Google Scholar, and 3 from other sources. Of the 5 articles considered for inclusion, 2 randomized trials and 1 systematic studies met the inclusion criteria.

Memory Rehabilitation

Recommended.

Memory rehabilitation is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Moderate**

Indications:	Memory problems post TBI. May be selectively indicated for mild TBI patients with significant memory deficits.
Benefits:	Improved recall and memory
Harms:	Negligible
Rationale:	There are one high-quality, 2 moderate-quality studies and one low-quality study evaluating memory rehabilitation.and many studies have incorporated such exercises as part of a rehabilitation program. Memory rehabilition is not invasive, has negligible adverse effects, has been purportedly successful for many years and 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: 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 342 articles in PubMed, 0 in Scopus, 0 in CINAHL, 0 in Cochrane Library, 22600 in Google Scholar, and 0 from other sources. We considered for inclusion 7 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 4 randomized trials and 3 systematic studies met the inclusion criteria.

Reading Comprehension Exercises

No Recommendation.

There is no recommendation for or against the use of reading comprehension exercises in the treatment of TBI patients.

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. There is one moderate quality trial suggesting simplified emergency department discharge instructions for head injury are preferable, but this does not test rehabilitation and is in mild TBI patients [766]. Reading Comprehension exercises are not invasive, have no adverse effects, are low cost, are thought to be helpful but in the absence of quality evidence, there is no recommendation.

Higher-order reasoning training has been used for treatment of TBI patients, in large part to develop skills to determine the gist meanings of information [768, 769]. Higher-Order Reasoning Training is typically short but intense programs that target the frontal lobe which provides an integrative approach to train functionally relevant complex reasoning abilities [768, 769]. 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 [769]. Training frontal-mediated top-down processes in adults with TBI is theorized to be beneficial in restoring and improving higher-order cognitive functions [769].

High-Order Reasoning Training

Recommended.

High-order reasoning training is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Low

Indications:	Moderate to severe TBI
Benefits:	Improved reasoning and better understanding gist of information
Harms:	Negligible
Frequency/Dose/Duration:	12 group sessions of 1.5hrs/session [768]. Taught SMART strategies. Reading materials used.
Rationale:	There is one moderate quality RCT suggesting some efficacy of higher-order reasoning among chronic TBI patients [768]. Hhigher-order reasoning training is not invasive, has not adverse effects, is moderately costly, has evidence of efficacy and tis thus recommended.
Evidence:	**Higher-Order Reasoning Training** – A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: **Higher-Order Reasoning Training**; **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 1 articles in PubMed, 0 in Scopus, 3 in CINAHL, 5 in Cochrane Library, 975 in Google Scholar, and 1 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Of the 3 articles considered for inclusion, 1 randomized trials and 2 systematic studies met the inclusion criteria.

Attention

Attention deficits are one of the most frequent cognitive consequences following the TBI, [771, 772]. Common treatment models include, APT-3 (basic sustained attention and executive controls), Attention Training Technique (Time Pressure management or 7 level models of training) [771].

Attention Process Training

Recommended.

Attention process training is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	For subacute to chronic, moderate and severe TBI patients. May apply to select mild TBI patients with these cognitive deficits.
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.
Benefits:	Improvement in performance of attention related tasks.
Harms:	Negligible
Rationale:	There are no quality studies involving APT. There is one [773] 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, apt, 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, 76 in Scopus, 5 in CINAHL, 1 in Cochrane Library, 1190 in Google Scholar, and 1 from other sources. We considered for inclusion 1 from PubMed, 0 from

Scopus, CINAHL, Cochrane Library, Google Scholar, and 1 from other sources. Of the 2 articles considered for inclusion, 1 randomized trials and 1 systematic studies met the inclusion criteria.

Recreational Computing

Recommended.

Recreational computing is recommended for the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Mild, moderate or severe, subacute or chronic TBI patients.
Frequency/Dose/Duration:	2 x 75-minute sessions per week for 6 weeks.
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve.
Benefits:	Increased attentional function
Harms:	Negligible
Rationale:	There is one low quality study [774] with a small sample suggesting the experimental group performed better on tests at 6 months (PASAT and WAIS-R). This intervention is not invasive, has negligible 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: recreational 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 1 articles in PubMed, 45 in Scopus, 0 in CINAHL, 0 in Cochrane Library, 1280 in Google Scholar, and 2 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 2 from other sources. Of the 2 articles considered for inclusion, 1 randomized trials and 1 systematic studies met the inclusion criteria.

COMPUTERIZED ATTENTION TRAINING WITH VISUAL, AUDITORY, AND DIVIDED TRAINING

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 post injury
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.
Benefits:	Improved attention measures.
Harms:	Negligible
Rationale:	There is one moderate quality study [456] suggesting Computerized Attention Training significantly improved on measures of attention. This 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: Traumatic brain injury, Closed Head injury, Penetrating Head Injury, Concussion Craniocerebral Injury, Computerized Attention Training with Visual, Auditory, and Divided training; 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 zero articles in PubMed, zero in Scopus, 30 in CINAHL, zero in Cochrane Library, 120 in Google Scholar, and zero from other sources. We considered for inclusion 2 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library, zero from Google Scholar, and zero from other sources. Of the 2 articles considered for inclusion, 2 randomized trials and zero systematic studies met the inclusion criteria.

"Captain's Log"- Computer Training Program for Attention Skills with Tasks for Vigilance, Inattention, Prudence, Impulsivity, Focus, Variability, and Speed

No Recommendation.

There is no recommendation for or against the use of "Captain's Log" in the treatment of TBI patients.

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 TBI patients. 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, computers, computer, software, program, 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 0 articles in PubMed, 1 in Scopus, 0 in CINAHL, 0 in Cochrane Library, 20 in Google Scholar, and 1 from other sources. We considered for inclusion 0 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 1 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria.

Restorative computer and non-computer attention remediation has been used to treat TBI patients [779-781].

Restorative Computer and Non-Computer Attention Remediation

No Recommendation.

There is no recommendation for or against the use of restorative computer and non-computer attention remediation in the treatment of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale:	There are no quality studies involving Restorative Computer and Non-Computer 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 Restorative Computer and Non-Computer Attention Remediation.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: 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 9 articles in PubMed, 425 in Scopus, 4 in CINAHL, 1 in Cochrane Library, 81 in Google Scholar, and 0 from other sources. We considered for inclusion 4 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 2 randomized trials and 1 systematic studies met the inclusion criteria.

Reaction time tests (arm movement reaction time, hand response with different levels of difficulty) have been used for saccadic deficits after severe head trauma [782-785].

Reaction Time Training

No Recommendation.

There is no recommendation for or against the use of reaction time training in the treatment of TBI patients.

Strength of Evidence **– No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale: There are no quality studies using Reaction time training. These techniques are not invasive, have low adverse effects, are moderate to high cost, and 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: 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 38 articles in PubMed, 1,709 in Scopus, 38 in CINAHL, 4 in Cochrane Library, 34,600 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 2 from other sources. Of the 4 articles considered for inclusion, 0 randomized trials and 1 systematic study met the inclusion criteria.

Balance

Vestibular dysfunction is repotedly common in TBI patients [168]. 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 [786]. Vestibular therapy aims to decrease these symptoms and improve dynamic and static balance by utilizing exercises that target these impairments [787]. 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 [788].

VESTIBULAR REHABILITATION

Recommended.

Vestibular rehabilitation is selectively recommended for TBI patients.
Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – **Low**

Indications:	Post TBI with vestibular symptoms thought to be peripheral and not central in origin. Generally initiated with electronystagmogram (ENG). Not indicated for concussion patients.
Benefits:	Faster resolution of vestibular symptoms
Harms:	Negligible
Frequency/Dose/Duration:	N/A
Indications for Discontinuation:	Sufficient recovery, resolution of symptoms.
Rationale:	There is one moderate quality study suggesting efficacy of Vestibular Rehab Treatment for treatment of TBI [696]. Vestibular Rehab Treatment 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, 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 31 articles in PubMed, 112 in Scopus, 4 in CINAHL, 0 in Cochrane Library, 240 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 3 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 1 randomized trial and 4 systematic studies met the inclusion criteria.

COMPUTER & VIDEO GAMES FOR BALANCE

Recommended.

Computer and video games for balance are recommended for use in the treatment of TBI patients.

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.
Frequency/Dose/Duration:	Two regimens have been used, either 20 hour long sessions, 3-5 times per week [792] or 15 minute stand balance training for 4 weeks [793].
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve.
Benefits:	Improved balance
Harms:	Negligible.
Rationale:	There are 2 moderate quality studies using video games [793, 794]. Both studies had small sample sizes. In [792], there was significant improvement in static balance and in [793], there was a weak positive trend towards increasing balance. Computer and video games are non invasive have low adverse effects, are moderate to high cost depending on supervision requirements and duration, and are recommended but 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 and Video Games, 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 5 articles in PubMed, 42 in Scopus, 1 in CINAHL, 6 in Cochrane Library, 2980 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 3 from other sources. Of the 3 articles considered for inclusion, 3 randomized trials and 3 systematic studies met the inclusion criteria.

VIRTUAL REALITY FOR BALANCE

Recommended.

Virtual reality for balance is recommended for use in the treatment of TBI patients.

Strength of Evidence – Recommended, Evidence (C)
Level of Confidence – Low

Indications:	In TBI patients physically able to use a VR system (be ambulatory), have good sitting balance and no perceptual disabilities which would prevent them from viewing the monitor where the virtual environment was displayed [797].
Frequency/Dose/Duration:	3 times per week for 25 minutes for a total of 4 weeks [797].
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve.
Benefits:	Improved memory, balance, reaction time, movement, visual and verbal learning tasks.
Harms:	Falls in unstable patients, dizziness, otherwise negligible
Rationale:	There are 7 moderate quality studies with most supporting modest efficacy [793, 797-802]. Yet, most of the studies have small sample sizes, or there are sparse methods. Larger studies are needed to clearly determine efficacy. Virtual reality games are non invasive have low adverse effects, but may be high cost if ongoing supervision is required, 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: Virtual Reality, Virtual Reality Program; Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating Craniocerebral Trauma, Virtual Reality, Virtual Reality Program; 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 35 articles in PubMed, 20 in Scopus, 12 in CINAHL, 8 in Cochrane Library, 14,100 in Google Scholar, and 0 from other sources. We considered for inclusion 6 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 7 from other sources. Of the 13 articles considered for inclusion, 9 randomized trials and 3 systematic studies met the inclusion criteria.

Perception and Self-Awareness and Psychological Well-Being

Perceptual deficits are common in adults with diffuse brain injury [803]. Perceptual training involves using tasks like construction of puzzles to improve functional performance [803]. Perceptual training can take place on the computer [804] or completing other functional tasks such as puzzles [803]. Perceptual training includes, basic visual scanning, somatosensory awareness and size estimation training, and complex visual perceptual organization [805].

Perceptual Skills Training

There is no recommendation for perceptual skills training for TBI patients.

No Recommendation.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale:	There are no quality studies specifically addressing perceptual skills training. These techniques are not invasive, have low adverse effects, are moderate to high cost, and 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: Perceptual skills training, brain injuries, closed head injuries, penetrating head injuries, brain concussion, concussion, craniocerebral trauma, traumatic brain injury, intracranial 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 1 article in PubMed, 32 in Scopus, 2 in CINAHL, 0 in Cochrane Library, 61,700 in Google Scholar, and 2 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 1 from other sources. Of the 5 articles considered for inclusion, 0 randomized trials and 4 systematic studies met the inclusion criteria.

In cognitive rehabilitation, verbal labeling training is used to provide feedback to TBI patients through tasks to improve performance [806]. The use of verbal and visual feedback improves self-awareness to TBI patients during occupational performances [806]. Interpersonal Process Recall (IPR) is a technique that specifically uses "videotaped interactions of participants with a professional in order to facilitate therapy" [807]. IPR is used specifically to help researchers "gain access to participants' silent in-session experiences as remembered by the participant" [808]. These silent experiences may include "feelings, emotions, body language, and subconscious reasoning [808]." Participants are "recorded interacting with a counselor and then are exposed to that recording with the counselor present" [807]. There is a "remote control present in case the participant or the counselor wishes to pause the recording at specific moments" [807]. IPR strives to "accelerate participants' recovery process with counseling by identifying underlying reasoning for specific actions during the interaction" [808].

Verbal Labeling Training and Compensatory Interpersonal Process Recall

Recommended.

Verbal labeling training and compensatory interpersonal process recall is selectively recommended for TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**

Level of Confidence – **Low**

Indications:	Moderate to severe chronic and post-op TBI patients with impaired self awareness and are at least one year post TBI.
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.
Benefits:	Improved self awareness
Harms:	Negligible
Rationale:	There is one moderate quality study [806] showing combination video plus virtual feedback was effective in TBI patients 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, traumatic, brain, injury, intracranial, closed, head, penetrating, concussion, 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 Scopus, 6 in CINAHL, 1 in Cochrane Library, 5720 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 5733 articles considered for inclusion, 1 randomized trial and 0 systematic studies met the inclusion criteria.

PSYCHOSOCIAL FUNCTIONING AND ADLS

Recommended.

Functionally based rehabilitation is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**

Level of Confidence – Low

Indications:	Moderate, severe, chronic and postop TBI patients 3-4 years post injury with ongoing deficits in functional independence, anxiety and depression [809].
Frequency/Dose/Duration:	2 sessions per week of 2-6 hours per week for 27 weeks
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve.
Benefits:	Self organization and psychological well being
Harms:	Negligible
Rationale:	There is one moderate quality study suggesting a multidisciplinary community outreach program post severe TBI is of benefit after the active treatment phase ended. 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: Psychosocial functioning and ADLs, Traumatic brain injury (mild, moderate, severe, acute, subacute chronic), Closed Head Penetrating 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 366 articles in PubMed, 18 in Scopus, 24 in CINAHL, 1 in Cochrane Library, 120 in Google Scholar, and zero from other sources. We considered for inclusion 2 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library, zero from Google Scholar, and zero from other sources. Of the 2 articles considered for inclusion, 1 randomized trial and 1 systematic studies met the inclusion criteria.

Memory and Motor Imagery

Memory and reasoning tasks are used as cognitive rehabilitation utilizing accept methods in TBI patients [810, 811]. Some specific methods include computer memory retaining groups, games, reasonings tasks.

MEMORY/REASONING TASKS, GAMES, COMPUTER GAMES

Recommended.

MEMORY/REASONING TASKS, GAMES, COMPUTER GAMES ARE SELECTIVELY RECOMMENDED FOR TBI PATIENTS.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Moderate, severe, postoperative , chronic TBI patients with ongoing memory deficits injured at least one to seven years previously, with adequate interpersonal communication skills, 25% intact visual fields, motivated and no premorbid history of psychiatric disturbance [810].
Frequency/Dose/Duration:	Daily treatment for 4 days per week (5 hours per day for 20 treatment hours per week) totaling 160 hours of treatment.
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve
Benefits:	Memory improvement
Harms:	Negligible
Rationale:	There are 2 low quality studies, with one suggested some benefit from computer games on memory performance [810]. 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: Traumatic brain injury (mild, moderate, severe, acute, subacute chronic) Closed Head Penetrating Concussion, Craniocerebral Injury Memory/reasoning tasks, games, computer games; 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 zero articles in PubMed, 77 in Scopus, zero in CINAHL, zero in Cochrane Library, 80 in Google Scholar, and zero from other sources. We considered for inclusion zero from PubMed, 2 from Scopus, zero from CINAHL, zero from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Of the 4 articles considered for inclusion, 2 randomized trials and 1 systematic study met the inclusion criteria.

COMPUTER MEMORY RETRAINING GROUP (CMRG)

Recommended.

Rehabilitation Programs

Computer Memory Retraining Group is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Evidence (C)**

Level of Confidence – Low

Indications:	Moderate, severe, postop, chronic TBI patients 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
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
Benefits:	Improved memory functions.
Harms:	Negligible
Rationale:	There is one moderate quality study [812] and one low quality study [813] showing CMRG improves memory retraining. This is a non-invasive, has negligible adverse effects, moderate-high cost and with evidence suggesting efficacy 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: Computer Memory Retraining Group, (CMRG); Traumatic brain, Intracranial, Closed Head, Penetrating head, Craniocerebral, injury, trauma, Concussion; 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, 7 in Scopus, 0 in CINAHL, 0 in Cochrane Library, 4330 in Google Scholar, and 2 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Of the 3 articles considered for inclusion, 2 randomized trials and 1 systematic studies met the inclusion criteria.

Handheld computers have been used by TBI patients to assist in memory [814].

HANDHELD COMPUTERS AS MEMORY AIDS

Recommended.

Handheld computers are recommended for use in the treatment of TBI patients.

Strength of Evidence – **Moderately Recommended, Evidence (B)**
Level of Confidence – Moderate

Indications:	Moderate or Severe TBI patients who had emerged from post-traumatic amnesia, had ongoing memory problems who also had sufficient hand function to use a PDA.
Benefits:	Improve memory and reducing forgetfulness.
Harms:	Negligible.
Frequency/Dose/Duration:	N/A
Rationale:	A high quality trial suggested superior performance on memory goals after use of a handheld computer [814]. Handheld computerized aids are not invasive, have no adverse effects, are high cost, have evidence of efficacy, and thus are recommended for selective treatment of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: attention test, sustained attention to response task or monotone counting or variables of attention test, traumatic brain injury, intracranial injury, closed head injury penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; sensitivity and specificity, predictive value of tests, gold-standard, accurate, accuracy, precision, precise, test; diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed articles in 747 PubMed, 310 in Scopus, 496 in CINAHL, 4 in Cochrane Library, 25800 in Google Scholar, and 8 from other sources. We considered for inclusion 11 from PubMed, 8 from Scopus, 2 from CINAHL, 3 from Cochrane Library, 3 from Google Scholar, and 8 from other sources. Of the 35 articles considered for inclusion, 19 prognostic studies, 1 randomized trial and 5 systematic studies met the inclusion criteria.

RESTORATIVE IMAGERY TRAINING

Restorative imagery training is selectively recommended for severe TBI patients.

Recommended.

Strength of Evidence – **Moderately Recommended, Evidence (B)**
Level of Confidence – Moderate

Indications:	Severe, postop, chronic TBI patients with ongoing deficits approximately 8 years post injury with a mean GCS of about 5
Frequency/Dose/Duration:	2 sessions per week 45-60 minutes long using imagery from Story Memory Technique (mSMT) for 5 weeks. [817].
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve
Benefits:	Improved memory and learning functions in addition to improved motor imagery [816].
Harms:	Negligible
Rationale:	There is one high quality study on Restorative Imagery training for memory improvement that [817] suggests improved memory and learning. There is one moderate quality study [816] showing some benefit in restoration of motor imagery. Restorative Imagery Training is non-invasive, has negligible adverse effects, moderate-high cost and with evidence suggesting efficacy is therefore 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, traumatic, brain, injury, intracranial, closed, head, penetrating, concussion, 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, 5 in Scopus, 1 in CINAHL, 0 in Cochrane Library, 3380 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 3389 articles considered for inclusion, 2 randomized trials and 2 systematic studies met the inclusion criteria.

Restorative Functional Skills Training

There is no recommendation for the use of restorative functional skills training in the treatment of TBI patients.

No Recommendation.

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 non-invasive, has negligible adverse effects, moderate-high cost, but 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, closed, head, penetrating, concussion, 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 Scopus, 1 in CINAHL, 0 in Cochrane Library, 767 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 777 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria.

Repetition of a certain activity is used to improve recovery in patients after brain injury [820]. However repetitive training is a time consuming process and patients often report boredom [820]. Play-based interventions to stimulate enjoyment is one approach being used to overcome such difficulties [820].

Games, Art, and Self-Expression

Games, art and self-expression are recommended for use in the treatment of TBI patients.

Recommended.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	TBI patients between 1 and 7 years post injury. Evidence best for mild TBI patients [821] but more severe TBI patient are thought to potentially benefit
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 [821].
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve
Benefits:	Improved memory function
Harms:	Negligible
Rationale:	There is one moderate quality study involving the use of Games, Art and Self Expression techniques which suggested modest efficacy [821]. These are non-invasive, have negligible adverse effects, 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: Game, puzzle, toy, art, self-expression, play, 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 937 articles in PubMed, 51 in Scopus, 61 in CINAHL, 3 in Cochrane Library, 3,240 in Google Scholar, and zero from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 1 from other sources. Of the 2 articles considered for inclusion, 1 randomized trial and 1 systematic study met the inclusion criteria.

COMPUTER-ASSISTED COGNITIVE REHABILITATION

Computer-assisted cognitive rehabilitation is selectively recommended for the treatment of TBI patients.

Recommended.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Moderate

Indications: TBI 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 [702].

Frequency/Dose/Duration: 24 sessions of pre-cognitive training 3 times per week times 8 weeks.

Indications for Discontinuation: When desired improvement has been achieved, clinical plateau or failure to improve

Benefits: Improved memory span and other memory functions

Harms: Negligible

Rationale: There are 3 moderate quality studies [166, 702, 822], all suggesting efficacy although one [166] found short term and not long term improvement in global outcomes at one year. This technique is non-invasive, has negligible adverse events and is low to moderate cost depending on self-administration 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: Computer-Assisted Cognitive Rehabilitation, Traumatic brain injury, Intracranial injury, Closed head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Cognitive, Computer assisted; 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 22 articles in PubMed, 144 in Scopus, 43 in CINAHL, 3 in Cochrane Library, 8050 in Google Scholar, and 2 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 2 from CINAHL, 0 from Cochrane Library, 2 from

Google Scholar, and 3 from other sources. Of the 8 articles considered for inclusion, 8 randomized trials and 0 systematic studies met the inclusion criteria.

Problem Solving

GROUP SESSIONS FOR PROBLEM SOLVING, DISCUSSION OF SOCIAL ISOLATIONS AND FRUSTRATIONS
Recommended.

Group sessions for problem solving, discussion of social isolation and frustrations are selectively recommended for treatment of TBI patients.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Low

Indications:	TBI patients at least one year post TBI injury 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 [823].
Frequency/Dose/Duration:	Weekly for 12 weeks [824] to 24 weeks [823].
Indications for Discontinuation:	When desired improvement has been achieved, clinical plateau or failure to improve.
Benefits:	Improved communication, coping skills and problem solving.
Harms:	Negligible
Rationale:	There are 2 moderate quality studies involving group sessions for chronic TBI patients in comparison with either no or conventional treatment [824] and [823]. Both studies showed TBI patients improved at 6 months and one year. Group therapy is non-invasive, has negligible adverse effects and is moderate to high cost depending on duration and is thus 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, psychotherapy, session, sessions, therapy, social support, supportive 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 5,012 articles in PubMed, 3,083 in Scopus, 458 in CINAHL, 1,453 in Cochrane Library, 8,210 in Google Scholar, and 4 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 6 from other sources. Of the 7 articles considered for inclusion, 4 randomized trials and 2 systematic studies met the inclusion criteria.

Compensatory Skills Training

Compensatory skills training is recommended for treatment of TBI patients.

Recommended.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Moderate-severe TBI patients that includes difficult problem solving and executive dysfunction
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.
Benefits:	Improved problem solving, executive function, anxiety, self concept and interpersonal communication.
Harms:	Negligible
Rationale:	There is one moderate study involving compensatory skills training [828] suggesting STEP is efficacious in self reported TBI problem solving and executive function. The other 2 low quality studies both have small samples. One study shows comparable efficacy between both groups [829] and the other study [830] reported improved anxiety, self concept, interpersonal and communication skills compared to control group. This type of intervention is non-invasive, low-moderate cost depending upon therapist time and number of sessions and has negligible adverse effects 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: 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 4 articles in PubMed, 19 in Scopus, 5 in CINAHL, 1 in Cochrane Library, 10,200 in Google Scholar, and 5 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 from CINAHL, 1 from Cochrane Library, 0 from Google Scholar, and 5 from other sources. Of the 7 articles considered for inclusion, 3 randomized trials and 4 systematic studies met the inclusion criteria.

Restorative and Compensatory Computer Assisted Cognitive Remediation (CACR) and External Aids

There is no recommendation regarding restorative and compensatory computer assisted cognitive remediation and external aids for TBI patients.

No Recommendation.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There are no quality studies. Restorative and Compensatory CACR is not invasive, has negligible adverse effects and is low to moderate cost, and in the absence of quality evidence, there is no recommendation for or against its use.

Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: restorative compensatory computer assisted cognitive remediation or (CACR), 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, 51 in Scopus, 8 in CINAHL, 0 in Cochrane Library, 54 in Google Scholar, and 2 from other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 1 from other sources. Of the 4 articles considered for inclusion, 0 randomized trials and 4 systematic studies met the inclusion criteria.

Visual Training

There is a high incidence (greater than 50%) of visual and visual-cognitive disorders in neurologically impaired patients (traumatic brain injury, cerebral vascular accidents, multiple sclerosis etc.) [488]. 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 [489, 490]. One study evaluated improvements in visiual search among hemianopic patients [489], while the other compared explorative saccade and flicker training in hemianopic patients [490-494].

Visual training has been used for treatment of neurological deficits; however, the randomized studies are almost solely of stroke patients [489, 490]. One study evaluated improvements in visual search among hemianopic patients [489], while the other compared explorative saccade and flicker training in hemianopic patients [490].

VISION TRAINING

Recommended.

Vision training is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**

Level of Confidence – Low

Indications:	Moderate and severe TBI with any of: accommodation, blurred vision, ocular motility abnormalities, difficulty with gaze, tracking difficulties, diplopia, disequilibrium in visually stimulating environments, impaired visual memory, light sensitivity, visual-spatial processing and problems with visual field integrity.
Benefits:	Ability to improve visual symptoms
Harms:	Negligible.
Frequency/Dose/Duration:	Dependent on severity of symptoms, and progress.
Indications for Discontinuation:	Resolution of visual problems from TBI.
Rationale:	There are no quality studies assessing Vision Training in TBI patients. There are multiple low quality studies, including studies suggesting efficacy. Vision Training is not invasive, has no adverse effects, is moderate cost, and is recommended for patients with visual impairments related to TBI.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the

following terms: visual training, oculomotor training; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 164 articles in PubMed, 15 in Scopus, 12 in CINAHL, 281 in Cochrane Library, 63,600 in Google Scholar, and 3 from other sources. We considered for inclusion 3 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 3 from other sources. Of the 6 articles considered for inclusion, 6 randomized trials and 0 systematic studies met the inclusion criteria.

OCULOMOTOR TRAINING

Recommended.

Oculomotor training is recommended for the treatment of TBI patients.
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 60minute sessions/week for 9 sessions total [495].
Indications for Discontinuation:	Resolution, completion of a course of treatment.
Rationale:	There is one moderate-quality trial in the military suggesting efficacy of Oculomotor Training for rehabilitation of TIB [495]. 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 TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: visual training, oculomotor training; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma**;** diagnostic, diagnosis, sensitivity, specificity, positive predictive value, negative predictive value, and predictive value of tests, efficacy, and efficiency. We found and reviewed 164 articles in PubMed, 15 in Scopus, 12 in CINAHL, 281 in Cochrane Library, 63,600 in Google Scholar, and 3 from other sources. We considered for inclusion 3 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 3 from other sources. Of the 6 articles considered for inclusion, 1 randomized trial and 0 systematic studies met the inclusion criteria.

Medication Recommendations

Non-Steroidal Anti-Inflammatory Medications

Non-steroidal anti-inflammatory (NSAIDs) have been used for treatment of traumatic brain injuries, although mostly for febrile control [835-837]. A few studies reviewed potential NSAID use for intracerebral pressure control [837, 838]. Some have theorized that NSAIDs may be helpful in neuroregenerative processes [839], 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 [840].

NSAIDs for TBI Patients

No Recommendation.

There is no recommendation for or against NSAIDs for treatment of TBI. There are other indications for TBI 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.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: Traumatic brain injury, intracranial injury, closed Head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral Trauma, anti-Inflammatory Agent, pharmacological action, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 123 articles in PubMed, 13 in Scopus, 5 in CINAHL, 5 in Cochrane Library and 0 in other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria. There is 1 moderate-quality randomized controlled trial.

NSAIDs for Febrile Control

Recommended.

NSAIDs are recommended for treatment of fever in TBI patients, with preference for continuous I.V. infusion over boluses [835].

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Moderate-severe TBI with fever.
Frequency/Dose/Duration:	Diclofenac low-dose infusion: initial I.V. bolus 0.2 mg/kg diluted in 100 ml NS then a continuous infusion of 75 mg in 50 ml normal saline until internal temperature was lower than 38ºC for at least 12 hours [835].
Indications for Discontinuation:	Satisfactory temperature control
Benefits:	Improved febrile control. May improve CNS outcomes
Harms:	Hemorrhage, especially GI or CNS.
Rationale:	There are no quality trials of NSAIDs compared with placebo for treatment of TBI patients. One moderate quality trial for treatment of fever found continuous NSAID infusion superior to boluses for control

	of fevers in comatose patients [835]. NSAIDs are not invasive, have low adverse effects in employed populations although somewhat higher in ICU settings, and are low cost. There is moderate quality evidence of efficacy for febrile suppression among patients treated with continuous I.V. NSAID infusion.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: Traumatic brain injury, intracranial injury, closed Head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral Trauma, anti-Inflammatory Agent, pharmacological action, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 123 articles in PubMed, 13 in Scopus, 5 in CINAHL, 5 in Cochrane Library and 0 in other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria. There is 1 moderate-quality randomized controlled trial.

Dextromethorphan (Nuedexta®) for TBI Patients

Dextromethorphan/quinidine has been used for treatment of pseudobulbar affect in adults with underlying neurological conditions [841] [842, 843].

Dextromethorphan for TBI Patients

No Recommendation.

There is no recommendation for the use of dextromethorphan in the treatment of TBI patients.
Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Has been used for emotional dyscontrol accompanying TBI. Also has been used to treat 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 is not invasive has some adverse effects, is low to moderate cost. There are no quality studies addressing the use of dextromethorphan for TBI patients and thus there is no recommendation. Dextromethorphan also has other potential indications.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Nuedexta, Dextromethorphan, Quinidine, 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 zero articles in PubMed, 0 in Scopus, 1 in CINAHL, 2 in Cochrane Library, 27 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the one article considered for inclusion, zero randomized trials and 1 systematic study met the inclusion criteria.

Cytoprotective Drugs for TBI Patients

There are two main reasons for using cytoprotective drugs in TBI patients: [170] 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,[844, 845].

Proton Pump Inhibitors (PPIs)

Strongly Recommended.

Proton pump inhibitors are strongly recommended for use with NSAIDs for select TBI patients.

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.
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 [846, 847].
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).(306, 307, 342, 346, 354, 355) [848-853]. 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.(356-365) [854-863]. There is only one quality head-to-head trial, and it found no difference in efficacy between pantoprazole and omeprazole(358) [855]. Misoprostol has also been consistently shown to be effective compared with placebo.(366-375) [845, 864] [865-867]; [868] [869] [870, 871] Relatively fewer studies have shown sucralfate to be effective compared with placebo;(376) [872] H2 blockers appear more effective for treatment of duodenal than gastric mucosa.(319-321) [873] [874] [875]. 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.(315, 377) [876] [845]. No difference was found

between famotidine and lansoprazole.(378) [877] Misoprostol has been reported superior to ranitidine,(379, 380) [859] [864] cimetidine, (381) [867] and sucralfate.(371, 382) [878] [867]. 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 (383) [879].

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 inhibitors, PPIs, critical care, intensive care unit, ICU, emergency room, ER; traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma; systematic, systematic review. We found and reviewed 1 article in PubMed, 16 in Scopus, 0 in CINAHL, 63 in Cochrane Library, 653 in Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Sucralfate

Recommended.

Group sessions for problem solving, discussion of social isolation and frustrations are selectively recommended for treatment of TBI patients.

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.

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 [846] [847].

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) (306, 307, 342, 346, 354, 355) [848] [849] [850, 851] [852] [853].
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.(356-365) [854], [855] [856] [857] [858] [859] [860, 861] [862] [863]) There is only one quality head-to-head trial, and it found no difference in efficacy between pantoprazole and omeprazole.(358) [855] Misoprostol has also been consistently shown to be effective compared with placebo.(366-375) [880] [864-867] [868] [869] [870] [871]. Relatively fewer studies have shown sucralfate to be effective compared with placebo (376) [872] H2 blockers appear more effective for treatment of duodenal than gastric mucosa (319-321) [873] [874] [875]. 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 (315, 377) [876] [845]. No difference was found between famotidine and lansoprazole (378) [877] Misoprostol has been reported superior to ranitidine, (379, 380) ([859] [864] cimetidine,(381) [867] and sucralfate.(371, 382) [878] [867]. 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 (383) [879].

Evidence:

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: sucralfate, critical care, intensive care unit, ICU, emergency room, ER; 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, 26 in Scopus, 0 in CINAHL, 3 in Cochrane Library, 2,185 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 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 study met the inclusion criteria.

H2 Blockers

Recommended.

H2-blockers are selectively recommended for treatment of TBI patients.
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.
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 [846] [847].
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) (306, 307, 342, 346, 354, 355) [848] [849-851] [852] [853]. 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.(356-365) [854], [855] [856] [857] [858] [859] [861, 881] [862] [863]) There is only one quality head-to-head trial, and it found no difference in efficacy between pantoprazole and omeprazole.(358) [855] Misoprostol has also been consistently shown to be effective compared with placebo.(366-375) [880] [815] [865] [866, 867]; [868] [869] [870] [871] Relatively fewer studies have shown sucralfate to be effective compared with placebo;(376) [882] H2 blockers appear more effective for treatment of duodenal than gastric mucosa [873] [874] [875]. 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 (315, 377) [876] [845]. No difference was found between famotidine and lansoprazole (378) [877] Misoprostol has been reported superior to ranitidine, (379, 380) [859] [864] cimetidine, [867] and sucralfate [878] [867]. 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 [879].

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: sucralfate, critical care, intensive care unit, ICU, emergency room, ER; 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, 26 in Scopus, 0 in CINAHL, 3 in Cochrane Library, 2,185 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 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 study met the inclusion criteria.

Other Medications

Magnesium for TBI Patients

Not Recommended.

Magnesium is not recommended for TBI patients [884, 885], other than magnesium-deficient patients.

Strength of Evidence – Acute TBI – **Moderately Not Recommended, Evidence (B)**

Strength of Evidence – Subacute, Chronic, pre/peri/post-operative– **Not Recommended, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale: There is one high-quality trial among acute TBI patients suggesting lack of efficacy for treatment of moderate to severe TBI patients [884]. The other trial was only partially completed and was low quality [885]. With one high-quality trial suggesting lack of efficacy, magnesium is moderately not recommended for treatment of acute TBI patients. It is not recommended (insufficient evidence) for treatment of other TBI patients absent evidence of Mg nutritional deficiency.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: magnesium, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 118 articles in PubMed, 387 in Scopus, 20 in CINAHL, 48 in Cochrane Library and 1 in other sources. We considered for inclusion 11 from PubMed, zero

from Scopus, zero from CINAHL, zero from Cochrane Library, and one from other sources. Of the 12 articles considered for inclusion, 2 randomized trials and zero systematic studies met the inclusion criteria. There is 1 high-quality and 1 low-quality RCT incorporated into this analysis.

Progesterone for TBI Patients

Not Recommended.

Progesterone is not recommended for TBI patients.

Strength of Evidence (Acute, Moderate to severe) – **Strongly Not Recommended, Evidence (A)**

Strength of Evidence (Subacute, Chronic and/or Mild, pre/peri/postoperative) – **Not Recommended, Insufficient Evidence (I)**

Level of Confidence – High

Rationale: There are 2 high-quality, sizable trials of progesterone for moderate to severe, acute TBI patients with neither showing benefits [892] [888] and one showing increased risk of phlebitis [892]. Two smaller-sized trials had suggested some potential benefits [889] [887]. 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 and is thus not recommended.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: progesterone, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 118 articles in PubMed, 387 in Scopus, 20 in CINAHL, 48 in Cochrane Library and 1 in other sources. We considered for inclusion 11 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library, and one from other sources. Of the 12 articles considered for inclusion, 6 randomized trials and zero systematic studies met the inclusion criteria.

Bromocriptine

Bromocriptine is a dopamine receptor agonist that affects D2 and partially affects D1 receptors. D2 sites reportedly are involved in head injured patients 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 [893-895] and [896].

BROMOCRIPTINE FOR TBI PATIENTS

No Recommendation.

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

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale:	There are 3 small, moderate-quality crossover trials with conflicting results regarding efficacy [893-895] and thus there is no recommendation for or against bromocriptine.
Evidence:	A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: bromocriptine, traumatic brain injury, brain injuries, intracranial injury, closed head injury, penetrating head injury, brain concussion, concussion, craniocerebral trauma, craniocerebral injury, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. In PubMed we found and reviewed 52 articles, and considered 14 for inclusion. In Scopus, we found and reviewed 103 articles, and considered zero for inclusion. In CINAHL, we found and reviewed 22 articles, and considered zero for inclusion. In Cochrane Library, we found and reviewed 4 articles, and considered zero for inclusion. We also considered for inclusion zero articles from other sources. Of the 14 articles considered for inclusion, 3 randomized trials and 1 systematic studies met the inclusion criteria. There are 3 moderate-quality RCTs incorporated into this analysis.

Cyclosporine for TBI Patients

No Recommendation.

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

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 TBI patients and found a non-significant trend suggesting improved functional outcomes [897]. 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 multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: cyclosporine, brain injuries, head injuries closed, head injuries penetrating, brain concussion, concussion, craniocerebral trauma, traumatic brain, intracranial, closed head, penetrating head or craniocerebral, injury, injuries, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. In PubMed we found and reviewed 25 articles, and considered 6 for inclusion. In Scopus, we found and reviewed 80 articles, and considered 1 for inclusion. In CINAHL, we found and reviewed zero articles, and considered zero for inclusion. In Cochrane Library, we found and reviewed 9 articles, and considered zero for inclusion. We also considered for inclusion zero articles from other sources. Of the 7 articles considered for inclusion, 5 randomized trials and zero systematic studies met the inclusion criteria. There are 4 moderate-quality RCTs incorporated into this analysis. There is 1 low-quality RCT. There are zero systematic reviews.

Donepezil for TBI Patients

Recommended.

Donepezil is recommended for TBI patients.

Strength of Evidence (Subacute, Chronic) – **Recommended, Evidence (C)**

Strength of Evidence (Acute, Pre/Peri/Postoperative) – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Particularly for subacute or chronic TBI with attention and/or short-term memory impairments [905].
Frequency/Dose/Duration:	Trial was of 10 weeks duration [905]. It is unclear if longer duration has any added benefits.
Indications for Discontinuation:	Adverse effects, satisfactory recovery.
Benefits:	Improvements in memory and attention
Harms:	Bowel frequency and incontinence [905].
Rationale:	There is one moderate-quality trial suggesting modest efficacy among subacute or chronic TBI patients for memory impairments [905]. A second trial lacked placebo control and reported comparable efficacy between Donepezil, Galantamine, and Rivastigmine [904]. 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 and Cochrane Library without date limits using the following terms Traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, brain concussion, craniocerebral injury, craniocerebral trauma, Aricept, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 12 articles in PubMed, 56 in Scopus, 11 in CINAHL, 3 in Cochrane Library and 0 in other sources. We considered for inclusion 4 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library and 1 from other sources. Of the 5 articles considered for inclusion, 2 randomized trials and 2 systematic studies met the inclusion criteria. There are 2 moderate-quality RCTs incorporated into this analysis. There are 2 systematic reviews.

Methylphenidate for TBI Patients

Recommended.

Medications (including topical creams)

Methylphenidate is recommended for TBI patients with cognitive deficits.

Strength of Evidence (Subacute) – **Moderately Recommended, Evidence (B)**

Strength of Evidence (Acute, Chronic) – Recommended, Insufficient Evidence (I)
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.
Frequency/Dose/Duration:	Six weeks [911]. 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
Benefits:	Improved memory, attention, cognition
Harms:	Difficulty sleeping, decreased appetite, blunted affect, nervous habits and mannerisms, and obsessive thinking. Infrequent hypertension and tachycardia [912]
Rationale:	There are multiple quality trials, most suggesting benefits. One study of 2-week duration showed improved information processing speed [913, 914]. A 6-week, moderate quality treatment trial suggested improved cognitive processing and attention [911]. One study showed some benefit with even a single dose although this study had a small sample size. [102]. Methylphenidate is not invasive, has relatively low adverse effects, is not costly and is recommended for treatment of TBI patients with cognitive and attentional deficits.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: Methylphenidate, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 54 articles in PubMed, 76 in Scopus, 29 in CINAHL, 2 in Cochrane Library and 0 from other sources. We considered for inclusion 19 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library and 1 from other sources. Of the 20 articles considered for inclusion, 15 randomized trials and 5 systematic studies met the inclusion criteria. There are 1 high- and 11 moderate-quality RCTs incorporated into this analysis. There are 2 low-quality RCTs. There are 5 systematic reviews.

Modafinil for TBI Patients

No Recommendation.

There is no recommendation for or against modafinil for TBI patients. It is primarily used for treatment of narcolepsy and hypersomnolence [916].

Strength of Evidence – No Recommendation, Insufficient Evidence (I)
Level of Confidence – Low

Rationale:	There are 3 moderate quality studies on Modafinil. One study, [917] showed some improvement in EDS and ability to stay awake but not in post-traumatic fatigue and [918] showed no benefit when compared to placebo. Thus, there is no recommendation for or against modafinil or armodafinil for TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: Modafinil and Armodafinil, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 11 articles in PubMed, 16 in Scopus, 0 in CINAHL, 4 in Cochrane Library and 0 in other sources. We considered for inclusion 10 from PubMed, 0 from Scopus, CINAHL, Cochrane Library and other sources. Of the 10 articles considered for inclusion, 3 randomized trials and 7 systematic studies met the inclusion criteria. There are 3 moderate-quality RCTs incorporated into this analysis. There are 7 systematic reviews.

Anti-spasticity Medications (Not Including Botox)

Anti-spasticity 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 [919-929]. Certain muscle relaxants, such as suxamethonium, offer sedative and relaxing properties without increasing intracranial pressure or reducing cerebral perfusion pressure [930].

ANTI-SPASTICITY MEDICATIONS FOR TBI PATIENTS

Recommended.

Anti-spasticity medications are recommended for treatment of TBI patients.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Low

Indications:	For treatment of discrete indications of muscle spasticity and dystonia associated with TBI. Otherwise, can be impairing and result in slowed mentation and potentially slowed recovery.
Frequency/Dose/Duration:	Medications typically used for this purpose include tizanidine, dantrium, baclofen. Per manufacturer's recommendations depending upon medication
Indications for Discontinuation:	Drowsiness, somnolence, bradycardia, hypertension, elevated liver enzymes, constipation
Rationale:	There is 1 moderate RCT [931] comparing Tizanidine to placebo. It suggested improvements in spasticity and hypertonia. There are 2 moderate quality studies showing comparable efficacy. Thus, muscle relaxants are recommended for treatment of spasticity and hypertonia. They have separate indications for other sequelae of accidents (e.g., see Low Back Disorders Guideline).
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: muscle relaxants, baclofen, carisoprodol, chlorzoxazone, chlorphenesin, cyclobenzaprine, dantrolene, diazepam, medazepam, mephenesin, meprobamate, metaxalone, methocarbamol, orphenadrine, quinine, tizanidine, tolperisone, xylazine, zoxazolamine, 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 studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 118 articles in PubMed, 423 in Scopus, 0 in CINAHL, 15 in Cochrane Library and 12 in other sources. We considered for inclusion 8 from PubMed, 3 from Scopus, 0 from CINAHL, 0 from Cochrane Library and 0 from other sources. Of the 11 articles considered for inclusion, 10 randomized trials and 1 systematic studies met the inclusion criteria. There are 3 moderate-quality RCTs incorporated into this analysis. There is 1 low-quality RCT.

Botulinum Toxin

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 over-dosed.
Frequency/Dose/Duration:	The highest quality placebo-controlled trial used Botulinum 100U in 5mL/2mL NS injection (above/below elbow diluant). 50U injected into each of FCR and FCU. Other muscles from shoulder to hand injected up to 500U [1074].
Indications for Discontinuation:	Sufficient resolution of spasticity, adverse effects.
Rationale:	Both moderate quality placebo-controlled trials suggested botulinum is superior for management of spasticity [1074, 1075], and one of the trials found comparable results to physiotherapy [1075]. Benefit durations of 18-22 weeks in the higher quality trial [1074]. Botulinum Toxin is invasive, has significant adverse effects especially if over-dosed, is high cost, but has evidence of treatment efficacy, and is recommended for treatment of spasticity related to TBI.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Traumatic, brain, injury, Intracranial, Closed, Head, Penetrating, Concussion, Concussion, Craniocerebral, Trauma, Penetrating, 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 70 articles in PubMed, 4 in Scopus, 32 in CINAHL, 1 in Cochrane Library, 4100 in Google Scholar, and 0 from other sources. We considered for inclusion 12 from PubMed, 0 from Scopus, 5 from CINAHL, 1 from Cochrane Library, 2 from Google Scholar, and 5 from other sources. Of the 24 articles considered for inclusion, 5 randomized trials and 19 systematic studies met the inclusion criteria.

Migraine Headache Medications

There are other classes of migraine headache medications that are FDA-approved for treatment of migraine headaches. These include triptans and ergot alkaloids.

TRIPTANS AND ERGOT ALKALOIDS FOR POST-TBI MIGRAINE HEADACHES

Recommended.

Migraine headache medications, including triptans and ergot alkaloids, are recommended for treatment of post-TBI migraine headaches.

Strength of Evidence – Recommended, Insufficient Evidence (I)
Level of Confidence – Moderate

Indications:	Post-TBI migraine headaches or post-concussive headaches.
Frequency/Dose/Duration:	Per manufacturer's recommendations
Indications for Discontinuation:	Adverse effects, intolerance, adverse effects, resolution of headaches
Rationale:	There are no quality trials for treating TBI patients. However, these medications have approved indications for treatment of migraines (Holland 12; Silberstein 12) and thus they are recommended for treatment of post-TBI patients.

Antiseizure Prophylaxis (Anticonvulsants)

Posttraumatic seizures are a frequent complication accompanying traumatic brain injuries [396, 932] [933]. 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 [396, 932-934].

ANTISEIZURE PROPHYLAXIS (ANTICONVULSANTS) FOR TBI PATIENTS

There is no recommendation for or against anti-seizure prophylaxis for severe or postoperative traumatic brain injury. Anti-seizure prophylaxis is not recommended for routine use in mild or moderate TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)** Severe TBI, Post-operative

Strength of Evidence – **Not Recommended, Insufficient Evidence (I)** Mild, moderate TBI
Level of Confidence – Low

Rationale:	There are no quality trials of efficacy in mild or moderate TBI patients. There is one moderate –quality study [933] suggests phenytoin prevents seizures through the first week post TBI [933]. A trial without placebo group had a trend towards more mortality in the valproate arm (13.4% vs. 7.2%, p=0.07) [935]. Another trial lacked a placebo group and suggested comparable efficacy [936]. Seizure prophylaxis is not invasive, has minimal short-term adverse effects but significant management issues over intermediate to long term and thus there is no recommendation for or against use in severe or post-operative TBI patients. Use is not recommended in mild and moderate TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 8 articles in PubMed, 53 in Scopus, 2 in CINAHL, 0 in Cochrane Library and 2 in other sources. We considered for inclusion 3 from PubMed, 0

from Scopus, 0 from CINAHL, 0 from Cochrane Library and 1 from other sources. Of the 5 articles considered for inclusion, 3 randomized trials and 1 systematic studies met the inclusion criteria. There are 3 moderate-quality RCTs incorporated into this analysis. There is 1 low-quality RCT.

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 [937-943] [944]. 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 has little effect on behavioral and cognitive issues [937]. Another study addressing depression after TBI with sertraline found improved recent verbal memory, visual memory, psychomotor speed and general cognitive efficiency [942]. Evidence remains conflicted for recommendation as other investigators have found sertraline not as effective as methylphenidate for improving cognitive function [941]. 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 [939].

Antidepressants for TBI Patients

Recommended.

Anti-depressants are recommended for treatment of TBI patients with depressive symptoms or depression.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	For the treatment of depression in TBI patients
Benefits:	Improvement in depressive symptoms in TBI patients.
Harms:	Intolerance, nausea, increased appetite, weight gain, fatigue, drowsiness, insomnia, dry mouth, blurred vision, drug-drug interactions
Frequency/Dose/Duration:	Per manufacturer's recommendations
Indications for Discontinuation:	Resolution of or significant improvement in depressive symptoms.
Rationale:	There are 6 moderate quality studies with mixed results; 2 suggesting efficacy [943],[938]) *and* 3 suggesting lack efficacy [940, 945], [946]. Thus, evidence specific to TBI is limited. Anti-depressants are not invasive, have some adverse effects and are low to moderate cost. They are indicated for treatment of depression or depressive symptoms.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: antidepressants, 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 studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 47 articles in PubMed, 69 in Scopus, 6 in CINAHL, 27 in Cochrane Library and 5 in other sources. We considered for inclusion 12 from PubMed, 2 from Scopus, 0 from CINAHL, 0 from Cochrane Library and 2 from other sources. Of the 12 articles considered for inclusion, 8 randomized trials and 4 systematic studies met the inclusion criteria. There are 6 moderate-quality RCTs incorporated into this analysis. There is 1 low-quality RCT.

Atypical Antipsychotics

Atypical antipsychotics have been used to treat psychotic disorders [947]. These drugs are classified as atypical due to an association with lower risk of causing extrapyramidal signs and symptoms (EPS) [948, 949]. Controversy surrounds the usage of these drugs for TBI treatment [950].

Atypical Antipsychotics for TBI Patients

Recommended.

Atypical antipsychotics are selectively recommended for treatment of TBI patients with agitation from mood disorders.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	For the treatment of agitation in TBI patients with mood disorders
Benefits:	Improvement in agitation and mood disorder symptoms in TBI patients.
Harms:	Intolerance, weight gain, fatigue, drowsiness, insomnia, dry mouth, blurred vision, drug-drug interactions. Caution is warranted in those with hypothalamic pituitary dysfunction.
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 in TBI patients. Some data suggest efficacy [951-954]. Atypical antipyschotics are not invasive, have some adverse effects and are low to moderate cost. Thus, these medications are recommended but lack sufficient evidence.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Valporic Acid, Depakote, Atypical Antipsychotic, Agitation; Traumatic brain injury, Intracranial injury, Closed Head injury Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma; Sensitivity, Specificity, Predictive Value of Tests, Gold-standard, accurate, accuracy, precision, precise, test 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 Scopus, 0 in CINAHL, 1 in Cochrane Library, 6 in Google Scholar, and 0 from other sources. Zero Articles met the inclusion criteria.

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 [955].

Mood Stabilizers for TBI Patients

There is no recommendation regarding mood stabilizers for treatment of TBI patients. There may be other indications for treatment with these agents.

No Recommendation.

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 TBI patients. Lithium may be indicated for treatment of mania and bipolar disorders that are beyond the scope of this guideline. Thus, there is no recommendation for or against the use of lithium for treatment of TBI patients.
Evidence:	Mood stabilizers – A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Mood Stabilizers, Lithium; Traumatic Brain 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 2 articles in PubMed, 7 in Scopus, 1 in CINAHL, 0 in Cochrane Library, 5,170 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 1 from CINAHL, 0from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 0 randomized trials and 4 systematic studies met the inclusion criteria.

Benzodiazepines

Benzodiazepines are typically used to treat anxiety, depression, panic attacks, nausea, seizures, vomiting and muscle spasms, but can also be used for sedation [956-959]. After experiencing a traumatic brain injury, benzodiazepines have been used to provide sedation before procedures, but effectiveness over other sedative agents is purportedly unclear [956-960].

BENZODIAZEPINES FOR TBI PATIENTS

Sometimes Recommended.

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

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	Not for use solely for TBI. Uses include discrete issues with anxiety, panic attacks, agitation, insomnia, alcohol withdrawal. As benzodiazepines impair memory and cognitive recovery, those TBI patients requiring a course of benzodiazepines after TBI (e.g., alcohol withdrawal) should be tapered as soon as practical.
Benefits:	Reduction in anxiety, panic attacks, hysteria. 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 TBI patients. There is only 1 moderate quality study [958] finding comparable efficacy between midazolam and propofol. No studies are compared tp placebo. Thus, evidence specific to TBI is limited. Benzodiazepines are not invasive, have some adverse effects and are low to moderate cost. They are not indicated for treatment of TBI. However, they may have discrete indications for treatment of anxiety, agitation, panic attacks, insomnia or alcohol withdrawal symptoms.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 37 articles in PubMed, 14 in Scopus, 1 in CINAHL, 1 in Cochrane Library and zero in other sources. We considered for inclusion 5 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library and zero from other sources. Of the 5 articles considered for inclusion, 3 randomized trials and 2 systematic studies met the inclusion criteria. There is 1 moderate-quality RCT incorporated into this analysis. There are 2 low-quality RCTs.

Corticosteroids

Corticosteroids has been used for treatment of acute TBI. The effect of corticosteroids on the risk of death has been reported in a past [961].

CORTICOSTEROIDS FOR TBI PATIENTS

Moderately Not Recommended.

Glucocorticosteroids are moderately not recommended for treatment of TBI.

Strength of Evidence – **Moderately Not Recommended, Evidence (B)**
Level of Confidence – Moderate

Rationale: There are 6 moderate quality studies involving glucocorticosteroids and 5 of these report lack of efficacy [962] [963, 964] [965] and [966]. Neither morbidity nor mortality was improved by the steroid. Steroids have evidence of efficacy for traumatic hyphema (see Eye Guideline). Glucocorticosteroids are either not invasive or minimally invasive depending on route of administration, have adverse effects, are low cost, but are not effective and thus are not indicated for treatment of TBI.

Evidence: A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: corticosteroids, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. In PubMed we found and reviewed 390 articles, and considered 5 for inclusion. In Scopus, we found and reviewed 39 articles, and considered 1 for inclusion. In CINAHL, we found and reviewed 5 articles, and considered zero for inclusion. In Cochrane Library, we found and reviewed 75 articles, and considered zero for inclusion. We also considered for inclusion zero articles from other sources. Of the 6 articles considered for inclusion, 6 randomized trials and zero systematic studies met the inclusion criteria. There are 5 moderate-quality RCTs incorporated into this analysis.

NMDA Receptor Antagonists (Excitatory Amino Acid Inhibitors)

Excitatory amino acid inhibitors prevent the reuptake of excitatory neurotransmitters, aspartate and glutamate, by interfering with excitatory amino acid transporters [967-972]. After experiencing a TBI, ionic imbalances in brain tissue purportedly result in excitoxic episodes that are thought to potentially lead to neuronal death [967, 970]. Amantadine is also considered an NMDA Receptor Antagonist and is considered separately below. 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 [969, 971].

Excitatory Amino Acid Inhibitors for TBI Patients

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 4 are moderate quality trials [970, 973, 974]. One pilot study suggested gacyclidine may be beneficial at high doses [973]. 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 and Cochrane Library without date limits using the following terms: traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, craniocerebral injury, craniocerebral trauma, excitatory amino acid antagonists, excitatory amino acid inhibitors, n-methyl-d-aspartate, neuroprotective agent, ampa/kainate receptor blockers, metabotropic receptor blockers, antagon, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 203 articles in PubMed, 43 in Scopus, 24 in CINAHL, 24 in Cochrane Library and zero in other sources. We considered for inclusion 19 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library and zero from other sources. Of the 14 articles considered for inclusion, 10 randomized trials and 4 systematic studies met the inclusion criteria. There are 4 moderate-quality RCTs incorporated into this analysis. There is 1 low-quality RCT.

Amantadine

Amantadine is a dopamine agonist and an *N*-methyl-D-aspartate (NMDA) glutamate receptor antagonist [975, 976]. Amantadine has been used for treatment of TBI patients [893, 896, 976-985].

Amantadine for Mild TBI Patients, Pre/Peri/Post-Operative

No Recommendation.

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

Strength of Evidence (Mild TBI, Pre/Peri/Post-operative) – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Moderate

Amantadine for Moderate and Severe, Subacute TBI Patients

Recommended.

Amantadine is moderately recommended for moderate and severe TBI patients.

Strength of Evidence (Subacute to early Chronic Phases, Severe TBI) – **Moderately Recommended, Evidence (B)**

Strength of Evidence (Subacute to early Chronic Phases, Moderate TBI) – **Recommended, Insufficient Evidence (I)**

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. [980]. Another trial enrolled TBI patients with irritability at 6 months after TBI and found efficacy for irritability [981].
Frequency/Dose/Duration:	Amantadine 100 mg 2x/day, then 150 mg 2x/day at 14 days, and 200 mg 2x/day at week 4 [980]. Another quality trial used 100mg QAM and at noon (B.I.D.) for 28 days [981].
Indications for Discontinuation:	Intolerance, adverse effects (see harms, below)
Benefits:	Earlier resolution of disabilities
Harms:	Vomiting, agitation, hypertonia, spasticity, insomnia, psychosis, hyperactivity, disorganization, vivid dreams, anorexia, aggression, delirium, and depression [980] [975] [976].
Rationale:	A high-quality RCT suggested amantadine is successful for treating functional deficits among subacute to chronic severe TBI patients [980]. The next highest quality trial suggested success to decrease irritability among those with chronic TBI and irritability among patients over 6 months beyond TBI [981]. 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 recommended for these select patients. It is recommended by inference for treatment of subacute or chronic moderate TBI patients with functional deficits or irritability. There is no recommendation for treatment of other TBI patients including mild, pre/peri/postoperative TBI patients.
Evidence:	A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: amantadine, traumatic brain injury, brain injuries, intracranial injury, closed head injury, penetrating head injury, brain concussion, concussion, craniocerebral trauma, craniocerebral injury, controlled clinical trial,

controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. In PubMed we found and reviewed 52 articles, and considered 14 for inclusion. In Scopus, we found and reviewed 103 articles, and considered zero for inclusion. In CINAHL, we found and reviewed 22 articles, and considered zero for inclusion. In Cochrane Library, we found and reviewed 4 articles, and considered zero for inclusion. We also considered for inclusion zero articles from other sources. Of the 14 articles considered for inclusion, 3 randomized trials and 1 systematic studies met the inclusion criteria. There are2 high- and 3 moderate-quality RCTs incorporated into this analysis. There is 1 low-quality RCT. There are2 systematic reviews.

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 TBI patients [968] [971]. Endocannabinoids have also been used to treat TBI patients [986].

CANNABINOIDS FOR TBI PATIENTS

No Recommendation.

There is no recommendation for or against cannabinoids for TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale: The overall breadth and depth of literature on these related subjects is sparse. A high quality trial of dexanabinol suggested no benefits of a single early dose on 6-month outcomes [968]. A moderate quality trial suggested lower intracranial pressures and a trend but no clear evidence of better long-term survival [971]. 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 [986]. With a lack of clear evidence of efficacy and the highest quality study being negative, there is no recommendation for or against dexanabinol or endocannabinoids for TBI patients.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: HU-211, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 5 articles in PubMed, 42 in Scopus, 0 in CINAHL, 6 in Cochrane Library and 0 from other sources. We considered for inclusion 3 from PubMed, 0 from Scopus, CINAHL, Cochrane Library and other sources.

Of the 3 articles considered for inclusion, 2 randomized trials and 1 systematic studies met the inclusion criteria. There is 1 high- and 2 moderate-quality RCTs incorporated into this analysis.

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 dementia and Parkinson's disease patients [987].

CEREBROLYSIN FOR TBI PATIENTS (NOT CURRENTLY APPROVED FOR USE IN U.S.)

No Recommendation.

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

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale:	There are 2 RCTs of Cerebrolysin. [988] is a pilot study and [989] performed an exploratory RCT on 208 ischemic stroke patients with promising results although a phase III trial is needed to confirm these results. Neither study clearly defined the dose, instead both identified volume of the drug (mL). While preliminary data suggest efficacy, Phase 3 trials are needed prior to a potential recommendation for TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; Sedatives, sedative hypnotics (zolpidem, propofol) and analgesics, narcotics (morphine sulfate, fentanyl, sufentanil), controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 265 articles in PubMed, 22 in Scopus, 12 in CINAHL, 1 in Cochrane Library and 2 in other sources. We considered for inclusion 8 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library and zero from other sources. Of the 8 articles considered for inclusion, 6 randomized trials and 2 systematic studies met the inclusion criteria. There is 1 high- and 1 moderate-quality RCTs incorporated into this analysis.
Comments:	This medication has not been approved for use in the US.

Tranexamic Acid

Tranexamic acid aids in reducing blood loss, or intracranial bleeding, associated with traumatic brain injury without increased occlusive events [990-993].

TRANEXAMIC ACID FOR TBI PATIENTS

Recommended.

Tranexamic acid is selectively recommended for treatment of TBI patients.

Strength of Evidence – Recommended, Evidence (C)
Level of Confidence – Moderate

Indications:	For selective use in TBI patients immediately post injury (1-3 hours) with either 1) evidence of intracranial hemorrhage or 2) strong suspicion of hemorrhage. The purpose is to reduce mortality risk and rebleeding and need for transfusion. [991]
Benefits:	Prevent further bleeding post TBI. Reduce risk of death. [991]
Harms:	Thromboembolic complications including hemorrhage and potential death.
Frequency/Dose/Duration:	Loading doses range from 2.5 mg/kg to 100 mg/kg and maintenance doses range from 0.25 mg/kg/hr. to 4 mg/kg/hr. delivered over 1-12 hours [991]
Indications for Discontinuation:	When patient is stable or complications arise from treatment with TXA.
Rationale:	(See also Eye Guideline for use of tranexamic acid for traumatic hyphema.) One quite large, high-quality study suggested TXA reduced risk of death by an absolute value of 1.5% (14.5% vs. 16.0%) if given within 3 hours [991]. There are 2 other studies of much smaller sample sizes, one of which is borderline significant. [993, 994]. TXA is minimally invasive, has adverse effects, and is costly, but has some evidence of efficacy in a highly select, at-risk population and is thus selectively recommended.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: tranexamic acid, amikapron, amstat, anvitoff, carxamin, cylcocapron, cyklokapron, emorhalt, frenolyse, mastop, rikavarin, tamcha, tranexamsaeure, tranexan, tranhexamic, transamin, trasamlon, ugurol, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 30 articles in PubMed, 18 in Scopus, 7 in CINAHL, 3 in Cochrane Library and 0 in other sources. We considered for inclusion 9 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library and 0 from other sources. Of the 9 articles considered for inclusion, 4 randomized trials and 5 systematic studies met the inclusion criteria. There are 2 high- and 1 moderate-quality RCTs incorporated into this analysis.

Sedatives, Sedative Hypnotics, and Opioids

A variety of agents in this classification have been used to treat TBI patients primarily for purposes of inducing and/or controlling sedation, including propofol [957-959, 995], ketamine [969, 996], midazolam [957-959, 996], fentanyl [996-999], remifentanil [998], sufentanil [969] [999], alfentanil [999], dexmedetomidine [995], morphine [997] [998]. 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.

Sedatives, Sedative Hypnotics, and Opioids for TBI Patients

No Recommendation.

Because these agents are used in hospital settings, there is no recommendation for or against sedatives, sedative hypnotics, and opioids for TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Evidence:

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; Sedatives, sedative hypnotics (zolpidem, propofol) and analgesics, narcotics (morphine sulfate, fentanyl, sufentanil), controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 265 articles in PubMed, 22 in Scopus, 12 in CINAHL, 1 in Cochrane Library and 2 in other sources. We considered for inclusion 8 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library and zero from other sources. Of the 8 articles considered for inclusion, 6 randomized trials and 2 systematic studies met the inclusion criteria. There are 3 moderate-quality RCTs incorporated into this analysis. There are 6 low-quality RCTs.

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 [934, 1000-1005].

BARBITURATES FOR TBI PATIENTS

Not Recommended.

Barbiturates are not recommended for treatment of TBI.

Strength of Evidence – **Not Recommended, Evidence (C)**
Level of Confidence – Low

Rationale:	There are 2 moderate quality studies. In one study, mannitol was considerably superior to pentobarbital for reducing mortality (41% vs. 77%) [542]. The other trial used a control arm that is no longer substantially used [1003]. As 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 and Cochrane Library without date limits using the following terms: brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 75 articles in PubMed, 24 in Scopus, 2 in CINAHL, 9 in Cochrane Library and 1 in other sources. We considered for inclusion 4 from PubMed, 2 from Scopus, zero from CINAHL, zero from Cochrane Library and 1 from other sources. Of the 5 articles considered for inclusion, 4 randomized trials and 3 systematic studies met the inclusion criteria. There are 2 moderate-quality RCTs incorporated into this analysis. There are 3 low-quality RCTs.

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 [1006-1009]. Beta blockers are believed to assist in controlling the effects of intracranial hemorrhaging, tachycardia, hypertension and intensity of agitation [977, 1006, 1007, 1009-1017]

BETA BLOCKERS FOR TBI PATIENTS

Recommended.

Beta-blockers are selectively recommended for treatment of TBI patients.

Strength of Evidence –Acute, moderate & severe, pre/peri/post-operative: **Recommended, Evidence (C)**

Strength of Evidence –Subacute, Chronic, mild: **Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Indications:	Selectively recommended for management of tachycardia in TBI patients. May be used as an option for hypertensive management.
Benefits:	Cessation of tachycardia and/or normalization of blood pressure
Harms:	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:	There are no quality trials of the general use of beta-blockers for management of TBI patients, thus there is no recommendation for general use among TBI patients. There are 2 moderate quality studies regarding beta blockers. One trial showed that atenolol reduced supraventricular tachycardia and ST-segment and T wave changes as well as appearance of less necrosis at autopsy [1018]. One trial found landiol effective for controlling tachycardia [1010]. A third trial addressed intubation and is thus not included here [1012]. Beta-blockers are either not invasive or minimally invasive, have modest risks, are low to moderate cost and have evidence of efficacy. They are recommended for selective treatment of patients with TBI. Benefits of ongoing treatment after the acute phase have not been shown specifically for TBI patients, but may be inferred based on treatment of either tachycardia and/or hypertension and thus are recommended by expert consensus.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: beta blockers, propranolol, pindolol, acebutolol, atenolol, bisoprolol, metoprolol, nadolol, propranolol, beta-adrenergic blocking agents, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 40 articles in PubMed, 13 in Scopus, 10 in CINAHL, 9 in Cochrane Library and 0 in other sources. We considered for inclusion 9 from PubMed, 5 from Scopus, 1 from CINAHL, 2 from Cochrane Library and 0 from other sources. Of the 17 articles considered for inclusion, 4 randomized trials and 7 systematic studies met the inclusion criteria.

There are 3 moderate-quality RCTs incorporated into this analysis. There is 1 low-quality RCT.

Aminosteroids

Aminosteriods have been shown to inhibit lipid peroxidation in animals and further randomized controlled trials have attempted to evaluate the effectiveness of tirilazad, an aminosteriod, in humans with head injuries. [1019].

AMINOSTEROIDS FOR TBI PATIENTS

Not Recommended.

Aminosteroids are not recommended for TBI patients.

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 [1019]. In [1020] results cannot be accurately interpreted due to 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 TBI patients.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: aminosteroids, 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 studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 8 articles in PubMed, 2 in Scopus, 0 in CINAHL, 1 in Cochrane Library and 0 in other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 1 from Cochrane Library and 0 from other sources. Of the 2 articles considered for inclusion, 1 randomized trials and 1 systematic studies met the inclusion criteria. There is 1 moderate-quality RCTs incorporated into this analysis. There is 1 systematic review.

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 [1021]. In TBI, CDP-choline purportedly may be beneficial for neuroprotection during the secondary injury phase and for neurofacilitation for improving recovery throughout rehabilitation [1021-1027].

CITICOLINE FOR TBI PATIENTS

No Recommendation.

There is no recommendation for or against citicholine for TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale: There are 2 moderate quality trials involving Citicholine. One study was terminated early for lack of utility [1028]. The other study suggested a slight benefit [1029] but sample size was small. in the absence of evidence of efficacy, there is no recommendation.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: Citicoline, cytidine diphosphate choline, citicholine, CDP choline, INN, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 36 articles in PubMed, 108 in Scopus, 3 in CINAHL, 2 in Cochrane Library and 0 from other sources. We considered for inclusion 7 from PubMed, 1 from Scopus, 1 from CINAHL, 1 from Cochrane Library and 0 from other sources. Of the 3 articles considered for inclusion, 1 randomized trials and 1 systematic studies met the inclusion criteria. There are 2 moderate-quality RCTs incorporated into this analysis. There are 3 low-quality RCTs. There are 4 systematic reviews.

Physostigmine (Eserine)

Physostigmine interrupts acetylcholine metabolism and inhibits acetylcholinesterase. It has been used as an aid in memory retention and cognitive function after traumatic brain injury [1030, 1031]. Scopolamine alternatively has been associated with memory impairments in some experimental studies [1032-1034], providing some rationale for physostigmine.

PHYSOSTIGMINE (ESERINE) FOR TBI PATIENTS

No Recommendation.

There is no recommendation for physostigmine for treatment of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale: There are 2 moderate quality studies from over 20 years ago with neither showing clear benefit of physostigmine [1030, 1031]. Thus, there is no recommendation for physostigmine.

Evidence: A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: Physostigmine, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 11 articles in PubMed, 26 in Scopus, 4 in CINAHL, 2 in Cochrane Library and zero in other sources. We considered for inclusion 6 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library and zero from other sources. Of the articles considered for inclusion, 6 randomized trials and 1 systematic studies met the inclusion criteria. There are 2 moderate-quality RCTs incorporated into this analysis.

Rivastigmine

The most common neurobehavioral consequences of TBI are cognitive impairments. Rivastigmine is a cholinesterase inhibitor that has been suggested to improve cholinergic function in patients with TBI [1035].

RIVASTIGMINE FOR TBI PATIENTS

Recommended.

Rivastigmine is recommended for treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	For TBI patients with moderate to severe memory deficits.
Benefits:	Improved cognitive function
Harms:	Nausea, vomiting, upper respiratory tract infection, vomiting, diarrhea, tremor, dizziness, drowsiness, anxiety, arthralgia, weakness.
Frequency/Dose/Duration:	Rivastigmine 1.5mg B.I.D. with food. Increased to 3.0mg B.I.D. at 4 wks. Increased to highest tolerated dose, up to 6 mg/day [1036].
Indications for Discontinuation:	Intolerance, adverse drug events or sufficient resolution of symptoms. The longest trial lasted 26 weeks as an open label [1035].
Rationale:	There are 3 studies using Rivastigmine for TBI. One trial with two reports suggests those with moderate to severe TBI showed improvements [1036] [1035] although the overall study trial was negative suggesting lack of benefit in mild TBI patients. Another trial has also suggested modest benefits [1037], although a third study found no advantage over Donepezil or Galantamine [904]. Adverse drug reactions are high [1037]. Rivastigmine is not invasive, has considerable adverse effects, is moderately costly and has some evidence of efficacy in moderate to severe TBI patients and is thus recommended.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: Rivastigmine, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 11 articles in PubMed, 26 in Scopus, 4 in CINAHL, 2 in Cochrane Library and zero in other sources. We considered for inclusion 6 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library and zero from other sources. Of the articles considered for inclusion, 0 randomized trials and 0 systematic studies met the inclusion criteria. There are 4 moderate-quality RCTs incorporated into this analysis.

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 [1038, 1039]. Memantine has been studied in rat models and thought to have neuroprotective potential for TBI patients [1040, 1041]. Substance P is proposed to have an important role in edema, and thus antagonists are proposed as neuroprotective [1042, 1043].

CABERGOLINE FOR TBI PATIENTS

No Recommendation.

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

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There is no quality studies of cabergoline and thus there is no recommendation.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: cabergoline; brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 0 articles in PubMed, Scopus, CINAHL, Cochrane Library and other sources. We considered for inclusion 0 from PubMed, Scopus, CINAHL, Cochrane Library and other sources. No articles met the inclusion criteria. There no quality studies for cabergoline for TBI patients.

Deamino Arginine Vasopressin (DDAVP) (Desmopressin)

Desmopressin is an ADH analog aimed at decreasing urine output by increasing the activity of ADH [1044]

DEAMINO ARGININE VASOPRESSIN (DDAVP) FOR TBI PATIENTS

Recommended.(For treatment of diabetes insipidus)

DDAVP is recommended for treatment of diabetes insipidus. Otherwise, there is no recommendation for or against DDAVP for TBI patients.

Strength of Evidence (Diabetes Insipidus) – **Recommended, Insufficient Evidence (I)**

Strength of Evidence (Lacking DI) – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Indications:	DDAVP (Cabergoline) is recommended for treatment of diabetes insipidus [1044] but there is no recommendation for use in TBI patients.
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 and thus there is no recommendation for general treatment of TBI patients. However, some patients do have indications for treatment of diabetes insipidus.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: Deamino arginine vasopressin, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed 4 articles in PubMed, 2 in Scopus, 0 in CINAHL, 1 in Cochrane Library and 0 in other sources. We considered for inclusion 0 articles from the databases and other sources. Zero randomized trials and systematic studies met the inclusion criteria. There are no quality studies on DDAVP for TBI patients.

Memantine

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 [1045] or Parkinson's disease or other types of dementia [1046].

MEMANTINE FOR TBI PATIENTS

No Recommendation.

Medications (including topical creams)

There is no recommendation for or against memantine for the treatment of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale:	There are no quality studies of memantine and thus there is no recommendation.
Evidence:	A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: memantine, traumatic brain injury, intracranial injury, closed head injury, penetrating head injury, concussion, craniocerebral injury, craniocerebral trauma, penetrating head trauma, closed head trauma, brain concussion, penetrating craniocerebral trauma, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed zero articles in PubMed, zero in Scopus, zero in CINAHL, zero in Cochrane Library and zero in other sources. We considered for inclusion zero from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library and zero from other sources. Of the zero articles considered for inclusion, zero randomized trials and zero systematic studies met the inclusion criteria. There are no quality studies on memantine for TBI patients.

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 [1047, 1048]. 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 [1043].

Substance P Antagonists for TBI Patients

No Recommendation.

There is no recommendation for or against substance P antagonists for the treatment of TBI patients.

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 and Cochrane Library without date limits using the following terms: Traumatic brain injury, intracranial injury, closed Head injury, penetrating head injury, concussion, brain concussion, craniocerebral Injury, craniocerebral Trauma, and neurokinin-1 Receptor Antagonists, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 2 articles in PubMed, 39 in Scopus, 0 in CINAHL, 0 in Cochrane Library and 0 in other sources. We considered for inclusion 1 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library and 0 from other sources. Of the 1 articles considered for inclusion, 0 randomized trials and 1 systematic studies met the inclusion criteria. There are no quality studies on Substance P antagonists for TBI patients.

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 [1049].

PIRACETAM FOR TBI PATIENTS

No Recommendation.

There is no recommendation for or against use of piracetam for treatment of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – Low

Rationale:	There are no quality studies of Piracetam and thus there is no recommendation.
Evidence:	**Piracetam** – A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Google Scholar and Cochrane Library without date limits using the following terms: piracetum, brain injuries, head injury or closed, penetrating, brain concussion or concussion, craniocerebral trauma, traumatic brain, intracranial or closed dead or penetrating head or craniocerebral; controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, retrospective studies, or prospective studies. We found and reviewed zero articles in PubMed, zero in Scopus, zero in CINAHL, zero in Cochrane Library and zero in other sources. We considered for inclusion zero from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library and zero from other sources. Zero articles met the inclusion criteria.

Complementary and Alternative Medicine

Complementary and alternative medications and homeopathy have been used for treatment of TBI patients [1050-1052].

Boswellia Serrata for TBI Patients

No Recommendation.

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

Strength of Evidence – No Recommendation, Insufficient Evidence (I)
Level of Confidence – Low

Rationale:	There is one moderate quality pilot study of Boswellia Serrata reporting a non-significant trend [1052], thus there is no recommendation for or against Boswellia Serrata..
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: complementary therapies, complementary and alternative medicine, integrative medicine, alternative therapies, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 118 articles in PubMed, 387 in Scopus, 20 in CINAHL, 48 in Cochrane Library and 1 in other sources. We considered for inclusion 11 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library, and one from other sources. Of the 12 articles considered for inclusion, 3 randomized trials and zero systematic studies met the inclusion criteria.

Other Alternative, Complementary, Homeopathic Treatments for TBI Patients

No Recommendation.

There is no recommendation for or against other alternative, complementary, or homeopathic treatments for TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	Homeopathic treatments were evaluated in two low quality studies [1050, 1051]. among patients 3 years after injury [1051], 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 and Cochrane Library without date limits using the following terms: complementary therapies, complementary and alternative medicine, integrative medicine, alternative therapies, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 118 articles in PubMed, 387 in Scopus, 20 in CINAHL, 48 in Cochrane Library and 1 in other sources. We considered for inclusion 11 from PubMed, zero from Scopus, zero from CINAHL, zero

from Cochrane Library, and one from other sources. Of the 12 articles considered for inclusion, 3 randomized trials and zero systematic studies met the inclusion criteria.
There is one moderate-quality RCTs incorporated into this analysis.
There are nosystematic reviews.

Infusion Therapy

Inthrathecal Baclofen (ITB) Pump for TBI Patients

Recommended.

Intrathecal baclofen is recommended for highly selective use among TBI patients.

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 [1053]. Should have severe hypertonia sufficient to interfere with activities of daily living [1053]. 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 one minute. Generally at least 2 trials of saline and intrathecal dose of baclofen 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 1 moderate quality study [1053] and one lower quality study showing some efficacy in reducing spasticity and dystonia in bilateral extremities [929]. Both studies were compared to placebo and both with small sample sizes. Neither involved implantation of a pump system. Baclofen administered intrathecally, especially by a pump, is invasive, has considerable adverse effects, is costly, but data suggest it is likely effective for a highly select TBI patient group.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: muscle relaxants, baclofen, carisoprodol, chlorzoxazone, chlorphenesin, cyclobenzaprine, dantrolene, diazepam, medazepam, mephenesin, meprobamate, metaxalone, methocarbamol, orphenadrine, quinine, tizanidine, tolperisone, xylazine, zoxazolamine, 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 studies, prospective studies, epidemiological studies, epidemiological research, and Nonexperimental Studies. We found and reviewed 118 articles in PubMed, 423 in Scopus, 0 in CINAHL, 15 in Cochrane Library and 12 in other sources. We considered for inclusion 8 from PubMed, 3 from Scopus, 0 from CINAHL, 0 from Cochrane Library and 0 from other sources. Of the 11 articles considered for inclusion, 10 randomized trials and 1 systematic studies met the inclusion criteria. There is 1 moderate RCT incorporated into this analysis. There is 1 low-quality RCT.

Injection Therapy

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 TBI patients, 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.

Radiofrequency Neurotomy, Neurotomy, or Facet Rhizotomy for Chronic Cervicothoracic Pain

No Recommendation.

There is no recommendation for or against the use of radiofrequency neurotomy, neurotomy, or facet rhizotomy for the treatment of chronic cervicothoracic pain confirmed with diagnostic blocks, but who do not have radiculopathy and who have failed conservative treatment.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Indications:	Chronic cervicothoracic pain patients without radiculopathy who failed conservative treatments and who have had a confirmed diagnosis by medial branch blocks.[1054]
Indications for Discontinuation:	Resolution of symptoms. If there is no response to the first procedure, there is no evidence that a second lesion will be beneficial.
Frequency/Dose/Duration:	One procedure might be tried after failure of non-invasive treatments including NSAIDs and a quality exercise program or as a means to help with participation in an active rehabilitation program. There is no recommendation for repeated procedures. It is reasonable to attempt a second lesion after 26 weeks in patients who had greater than 50% improvement in pain from first procedure for the first 8 weeks with a late return of pain.[1055] There is no recommendation for a third or for additional procedures. There is logically a limit as to how many times it is possible to permanently destroy the same nerve.

Radiofrequency Neurotomy for Cervicogenic Headache

Moderately Not Recommended.

Radiofrequency neurotomy is moderately not recommended for the treatment of cervicogenic headache.

Strength of Evidence – **Moderately Not Recommended, Evidence (B)**
Level of Confidence – **Low**

Occipital nerve blocks have been used to treat migraine and cervicogenic headaches [1056-1059]. Greater occipital nerve blockade has been used to treat episodic cluster headache [1060] and for migraines [1061].

Occipital Nerve Blocks

Recommended.

Occipital nerve blocks are recommended for the treatment of cervicogenic headache. There is no recommendation for or against occipital nerve blocks for the treatment of migraine headache.
For Cervicogenic Headache: *Strength of Evidence* – **Recommended, Evidence (C)**
Level of Confidence – Low

For Migraine Headache: *Strength of Evidence* – **No Recommendation, Insufficient Evidence (I)**
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 [1056]. Post-traumatic 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 [1056]. Rare procedure complications.
Frequency/Dose/Duration:	The highest quality study showing limited short-term efficacy for cervicogenic headaches used 10mL (3mL 2% lidocaine, 3mL 2% lidocaine with epinephrine 1:200,000, 2.5mL 0.5% bupivacaine, 0.5mL fentanyl 50µg/mL and 1mL clonidine 150 µg /mL).
Rationale:	There are 2 high quality trials with conflicting results, one suggesting efficacy for cervicogenic headache [1056] and one suggesting a lack of efficacy for migraines [1057], resulting in questions regarding whether efficacy may differ based on the diagnosis. Two moderate quality trials suggested efficacy for migraines [1058] [1059]. 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 [1062]. Nerve blocks are invasive, have some adverse effects, are moderate to high cost over time, and have some evidence of short-term efficacy and thus are 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: migraine disorders, Migraines,

Tension-Type Headache, neuralgia, cluster headache, post-traumatic headache, cervicogenic headache, 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 22 articles in PubMed, 7 in Cochrane Library, 4550 in Google Scholar, and 1 from other sources. We considered for inclusion 3 from PubMed, 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 studies met the inclusion criteria.

Occipital Nerve Stimulation (ONS)

Occipital nerve stimulation has been attempted both trancutaneously (non-invasive) [1063] and by implanted stimulator [1064-1067].

Non-Invasive Occipital and Supraorbital Nerve Stimulation (ONS)

Recommended.

Non-invasive occipital and supraorbital nerve stimulation is recommended for the treatment of TBI patients.

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 [1068]). Chronic migraine or tension headaches [1069] 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.) [1064]. At least 2 months of medication withdrawal for medication overuse headaches [1064].
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 30min./day for 2 weeks.
Rationale:	A few moderate quality RCTs found headache reductions compared with sham [1063]. One trial found the reductions lasted beyond the 2wks of treatment to the duration of the trial of 60 days with 86% v. 4% of non-allodynic patients achieving at least 50% reduction in headache days [1063]. Cutaneous nerve stimulation administered in sessions is not invasive, has minimal adverse effects, is high cost, and have some evidence of short- to intermediate-term efficacy and thus are 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: Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Peripheral Nerve Stimulation, 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 93 articles in PubMed, 756 in Scopus, 13 in CINAHL, 11 in Cochrane Library, 3770 in Google Scholar, and 4 from other sources. We considered for inclusion 0 from PubMed, 5 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 4 from other sources. Of the 13 articles considered for inclusion, 2 randomized trials and 8 systematic studies met the inclusion criteria

Implantable Occipital Nerve Stimulation (ONS) Devices

Not Recommended.

Implantable occipital nerve stimulation (ONS) devices are not recommended for use in the treatment of TBI patients.

Strength of Evidence – **Not Recommended, Insufficient Evidence (I)**
Level of Confidence – Low

Rationale:	There is one moderate quality trial suggesting lack of efficacy [1070]. There is one report of some efficacy in a longer-term, but open label trial for treatment of migraine headaches [1071]. 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. Implantable devices are invasive, have significant adverse effects, are high cost and 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 is on migraine headaches, which is of questionable use for treatment of TBI patients. These devices may be a consideration for limited use in those with normal psychological profiles, no evidence of malingering, and with 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: Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Peripheral Nerve Stimulation, 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 93 articles in PubMed, 756 in Scopus, 13 in CINAHL, 11 in Cochrane Library, 3770 in Google Scholar, and 4 from other sources. We considered for inclusion 0 from PubMed, 5 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 4 from other sources. Of the 13 articles considered for inclusion, 2 randomized trials and 8 systematic studies met the inclusion criteria*

Allied Health

A Meniett device is a device that is used for treating Meniere's disease [1076-1080]. Meniere's is a reported complication of trauma [1081].

Meniett Device

No Recommendation.

A Meniett device is recommended for use in the treatment of select TBI patients with Meniere's disease.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Indications:	Unilateral Meniere's with disruptive levels of vertigo, low frequency sensorineural hearing loss on audiometry, functional level of 2-4 (Ololaryngol Head Neck Surg 1995;113:181-185), abnormal cochleogram in the affected ear (SP/AP click ratio >0.39 or toneburst SP of ≥2.0μV) [1082].
Benefits:	Improved control of vertiginous symptoms, although differences at 4 months compared with sham relatively modest [1082].
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 [1082] [1083]. There are no quality studies assessing Meniett Device for treatment of TBI. Meniett Device is invasive, has some adverse effects, is high cost, has some evidence of efficacy in Meniere's patients and thus is selectively recommended (I) for treatment of vertigo both resistant to other treatment and passage of time from TBI, as well as of sufficient severity.
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, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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 Scopus, 0 in CINAHL, 0 in Cochrane Library, 24 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 3 from Google Scholar, and 0 from other sources. Out of the 3 articles considered for inclusion, 3 randomized trails and 0 systematic reviews met the inclusion criteria.

Transcranial Magnetic Stimulation (TMS)

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 [1084]. There have been attempts to use TMS for neurological conditions including TBI [1085-1090].

Transcranial Magnetic Stimulation (TMS)

No Recommendation.

There is no recommendation for or against the use of transcranial magnetic stimulation in the treatment of TBI patients.
Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There are no quality studies assessing Transcranial Magnetic Stimulation for treatment of TBI. Transcranial Magnetic Stimulation is not invasive, has no adverse effects, is high cost, but in the absence of quality evidence of effectiveness, there is no recommendation. There are other approved indications, including headache and depression.
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, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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 43 articles in PubMed, 229 in Scopus, 2 in CINAHL, 7 in Cochrane Library, 3870 in Google Scholar, and 4 from other sources. We considered for inclusion 4 from PubMed, 5 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 4 from other sources. Of the 13 articles considered for inclusion, 1 randomized trial and 7 systematic studies met the inclusion criteria. 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 [1091] [1092, 1093]. tDCS involves the application of a weak DC electric current to the scalp to modulate the neurons in the brain [1093] [1094]. tDCS applied on the motor cortex has been reported to increase the pain threshold and provide relief from neuropathic pain [1094].

Transcranial Direct Current Stimulation (TCDS)

No Recommendation.

Allied Health Interventions

There is no recommendation for or against the use of transcranial direct current stimulation in the treatment of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There are no quality studies assessing the utility of Transcranial Direct Current Stimulation for treatment of TBI. There are a few mechanistic studies suggesting potential utility, but they lack meaningful clinical followup and outcomes [1095] [1094]. Transcranial Direct Current Stimulation is not invasive has no adverse effects, is high cost, but with the lack of quality evidence of clinical 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: 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 15 articles in PubMed, 60 in Scopus, 2 in CINAHL, 31 in Cochrane Library, 40 in Google Scholar, and 0 from other sources. We considered for inclusion 3 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 2 randomized trials and 0 systematic studies met the inclusion criteria.

Manipulation and Mobilization

Manipulation and mobilization are two types of manual therapy. These include wide arrays of different techniques and schools of thought. Some consider these two interventions to be on a spectrum of velocity and applied force. In general, mobilization involves assisted, low-force, low-velocity movement within or at the limit of joint range of motion. Manipulation involves higher-force, higher-velocity, and low-amplitude action with a focus on moving a target joint.

From the standpoint of evidence-based practice guidelines development, there are numerous types of manipulation utilized in many different studies [1096-1104]. These issues result in difficulties comparing methods, techniques, or results across the available literature. Differences between techniques appear to be largely unstated in the available systematic reviews, which have aggregated all studies together. Adjustment is generally a synonym for manipulation in the chiropractic profession. There are studies evaluating thoracic manipulation for cervical pain without cervical manipulation [1105].

Many practitioners begin with lower force manipulation or mobilization techniques, and reserve higher force manipulation techniques for those who do not respond to lower force techniques to limit adverse effects and complications. Manipulation is generally considered a safe procedure, but like all other treatments is not without risks. For example, reported fatal outcomes have occurred and are particularly attributed to cervical manipulation [1106]. Reports of more severe but rare adverse effects include vertebrobasilar dissection, carotid artery injury, and disc herniation or spinal cord compression myelopathy, although these reports need to be considered in the context of natural progressions of cervical pain without any intervention [1107]. The mean age of patients experiencing vertebrobasilar dissection in the case reports is 38 and the risk has been reportedly due to cervical manipulation with a rotary component [1106]. However, more recent population based studies have questioned the incidence of vascular injury from manipulation, suggesting instead that this may more often be an acceleration or natural progression of an event in progress [1108]. Mobilization is less likely to lead to side effects than is manipulation.

The most common adverse response to neck manipulation is local discomfort that resolves within 24 to 48 hours [1106] [1106]. There have been reports of vertebral artery dissection that result in posterior circulation stroke purportedly following cervical manipulation [1098]. There has been much debate on the frequency of these events and multiple reports suggest low risk [1109]. Population-based case control study of all patients who seek chiropractic care in Ontario revealed a frequency of 8 cases occurred within 7 days of receiving chiropractic care in 109 million person years of observation in Ontario [1108]. Of particular interest was the observation that the odds ratio of a stroke occurring after a primary physician visit for cervical pain was the same as that noted following a chiropractic office visits, raising doubt as to whether there is any relationship between the manipulation and stroke. Vertebral artery dissections are heralded by cervical pain and frequently headache that can bring a patient to either a chiropractor or general physician's office, and if not recognized can progress to stroke that can be fatal. This should be considered in the differential diagnosis of cervical pain.

Manipulation/Mobilization for Acute, Subacute, or Chronic Cervicothoracic Pain

Recommended.

Manipulation/mobilization of the cervical and/or thoracic spine is recommended for short-term relief of cervical pain or as a component of an active treatment program focusing on active exercises for acute cervicothoracic pain. However, high amplitude, high velocity manipulation is not recommended.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Benefits:	Potential for faster resolution of pain and improved function.
Harms:	Worsening of neck pain, especially immediately after manipulation.
Frequency/Dose/Duration:	Dependent on severity. Most patients with more severe spine conditions may receive up to 12 visits over 6 to 8 weeks, typically one to 3 times a week;[1110-1112] total treatments dependent on response to therapy. Substantial progression (e.g., return to work or activities, increasing ability to tolerate exercise, reduced medication use) should be documented at each follow-up visit. Treatment plan should be reassessed after each 2-week interval. Most guidelines suggest that if there is significant response in the above outcomes, it is worth considering another 2 weeks of treatment. If no response to 2 weeks of application of a particular manipulation treatment, it should be discontinued and 2 weeks of a different method of manipulation/mobilization or other treatment should be considered. If there is no response after 4 weeks and two 2-week trials of different manipulation/mobilization techniques, it is unlikely that further manipulation/mobilization will be helpful.
Indications for Discontinuation:	Lack of demonstrated continued functional response after 6 manipulation/mobilization sessions (2 trials of 2 or more different methods), resolution of symptoms, or failure to participate in an active rehabilitation program.
Rationale:	Multiple studies evaluate thoracic and cervical spine manipulation, [1106, 1113] whereas other studies evaluated one or the other.[1100, 1111, 1114-1117] Other studies do not delineate between the two different types of therapies.[1097, 1118-1122] There are no quality trials comparing mobilization to sham or placebo for treatment of acute cervical pain. The closest study appears to be that of Cleland et al (2007), but it was impaired by methodological limitations. Most studies compare mobilization to manipulation, or use mobilization as a component of other interventions, significantly weakening the ability to infer efficacy of manipulation.[1123] Most studies had small samples sizes with most <70.[1111, 1112, 1124, 1125] A moderate-quality trial evaluating mobilization suggested greater benefit compared with directed exercise and continued care by a general practitioner. However, this study included acute, subacute, and chronic pain without delineation between duration in the results, and the general practitioner care appeared to fail to include treatments thought to be efficacious.[1126] A moderate-quality trial comparing cervical manipulation to mobilization suggested improvement in pain and range of motion in both groups after a single treatment, but manipulation was reportedly associated with overall better pain improvement on the NRS-101 and larger gains in range of motion [1127]. Thus, the available quality evidence conflicts on

treatment of cervicothoracic pain.[1128] Hoving suggested mobilization is a favorable treatment option for patients with cervical pain compared with directed exercise or continued care by a general practitioner, although the general medical care may have been suboptimal.[1126]

There are no sham-controlled trials of manipulation. Only a few RCTs evaluated subacute cervicothoracic pain and did so in combination with chronic cervicothoracic pain without reporting findings based on duration of symptoms. [1112] A moderate-quality study comparing a single episode of cervical manipulation versus mobilization in subacute and chronic patients reported manipulation to have greater improvement in cervicothoracic pain at rest and active range of motion.[1114] A moderate-quality study that did not describe well the duration of symptoms found an increase in range of motion after a single thoracic spine manipulation compared to no intervention.[1129] (Krauss 08) Where another study compared manipulation and exercises alone and in combination and reported no significant clinical differences at 12-month follow up in chronic pain patients.[1113]

A moderate-quality study of patients with chronic pain examined manipulation, manipulation and exercise and an exercise only group. They found that the manipulation alone group had less improvement compared to manipulation with exercise and exercises alone at 16 months after 11 weeks of treatment.[1113] One study of 119 patients with cervicothoracic pain greater than 3 months duration reported improvement in all groups, but did not find any difference in the manipulation group when compared to physiotherapy and intensive training of cervical musculature for 6 weeks.[1130] A moderate-quality study suggested acupuncture was more effective than manipulation or medications in treating chronic cervical pain.[1097] Another moderate-quality study compared manipulation with sham ultrasound to sham ultrasound alone and suggested an improvement in pain in the manipulation group at 12 weeks.[1131] While the RCTs show that other interventions are equally beneficial, the manipulation groups also experienced significant improvement in pain control and range of motion. Manipulation in subacute and chronic cervicothoracic pain is recommended and is best utilized in combination with an active exercise program.[1113, 1132] It was not possible to determine which technique was beneficial for which patient populations. There was also insufficient evidence for cervicothoracic pain with radicular findings.

A study evaluated a Clinical Prediction Rule for cervicothoracic pain using thoracic manipulation that is somewhat analogous to those for the lumbar spine (see Low Back Disorders guideline). They reported predictors for increasing the likelihood of a positive outcome with thoracic manipulation.[1133, 1134] These 6 variables were symptoms <30 days, no symptoms distal to the shoulder, neck extension does not aggravate pain, FABQPA score <12, diminished upper thoracic spine kyphosis, and cervical extension ROM <30 degrees. Once this information has been reproduced and validated there may be a group of patients identified where thoracic manipulation may be

	recommended with greater specificity. However, a recent RCT reported that the above CPR was not able to be validated.[1135] Another group assessed a clinical prediction rule and noted better response to treatment if: initial Neck Disability Index <11.5, bilateral involvement pattern, no sedentary work >5 hours a day, feeling better while moving the neck, not worse while extending the neck, and a diagnosis of spondylosis without radiculopathy.[1136]
Evidence:	There are 4 high-[1099, 1118, 1137, 1138] and 76 moderate-quality RCTs or crossover trials (one with two reports) incorporated into this analysis.[487, 1096, 1097, 1100, 1101, 1106, 1110, 1111, 1113-1116, 1119-1131, 1139-1189] There are 25 low-quality [1190-1216] RCTs and 5 other studies [1117, 1214, 1216-1218] in Appendix 1. A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: manipulation and mobilization, disorder terms-cervicalgia, neck pain, cervical pain, neck, cervical, vertebrae, vertebral, spine, radiculopathy, radiculopathies, radicular pain, intervertebral disc displacement, herniated, herniat*, displacement, displacements, displaced, disk, disc, disks, discs, pain, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Non-experimental Studies. In PubMed we found and reviewed 756 articles, and considered 130 for inclusion. In Scopus, we found and reviewed 1,436 articles, and considered 5 for inclusion. In CINAHL, we found and reviewed 134 articles, and considered 8 for inclusion. In Cochrane Library, we found and reviewed 32 articles, and considered 0 for inclusion. We also considered for inclusion 0 articles from other sources. Of the 143 articles considered for inclusion, 104 randomized trials and 13 systematic studies met the inclusion criteria.

Manipulation for Chronic Cervicogenic Headache Pain

Recommended.

Spinal manipulation of the cervical and/or thoracic spine is recommended for treatment of chronic cervicogenic headache pain.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – **Low**

Frequency/Dose/Duration:	Once or twice a week for 4 to 5 appointments, up to 8 total appointments recommended if there is benefit after 4 to 5 appointments.[487, 1219]
Indications for Discontinuation:	Resolution of symptoms, adverse effects from treatment, lack of demonstrated positive effect on headache intensity and/or frequency, or non-participation in an active rehabilitation therapy program.[1143]
Evidence:	There are 4 high-[1099, 1118, 1137, 1138] and 76 moderate-quality RCTs or crossover trials (one with two reports) incorporated into this analysis.[487, 1096, 1097, 1100, 1101, 1106, 1110, 1111, 1113-1116, 1119-1131, 1139-1189] There are 25 low-quality [1190-1216] RCTs and 5 other studies [1117, 1214, 1216-1218] in Appendix 1. A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: manipulation and mobilization, disorder terms-cervicalgia, neck pain, cervical pain, neck, cervical, vertebrae, vertebral, spine, radiculopathy, radiculopathies, radicular pain, intervertebral disc displacement, herniated, herniat*, displacement, displacements, displaced, disk, disc, disks, discs, pain, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Non-experimental Studies. In PubMed we found and reviewed 756 articles, and considered 130 for inclusion. In Scopus, we found and reviewed 1,436 articles, and considered 5 for inclusion. In CINAHL, we found and reviewed 134 articles, and considered 8 for inclusion. In Cochrane Library, we found and reviewed 32 articles, and considered 0 for inclusion. We also considered for inclusion 0 articles from other sources. Of the 143 articles considered for inclusion, 104 randomized trials and 13 systematic studies met the inclusion criteria.

Manipulation for Cervical Spine Conditions

Not Recommended.

High-amplitude, high-velocity spinal manipulation of the cervical and/or thoracic spine is not recommended for treatment of cervical spine conditions.

Strength of Evidence – **Not Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale: A moderate-quality study evaluated 80 patients with chronic cervicogenic headache randomized to either 8 or 16 spinal manipulation sessions in 8 weeks as the intervention group, and 8 or 16 sessions of "light massage" as the control group. The authors reported both clinical and statistical benefit of manipulation lasting up to 24 weeks with decreased reported pain and decreased reported analgesic use. There was no clear benefit of 16 versus 8 visits.[487] A moderate-quality study evaluated cervical manipulation with sham manipulation in a modified crossover study design suggested improvement with cervical range of motion, but did not find improvement in headache pain.[1152] Another moderate-quality study in headache patients evaluated cervical manipulation compared to low level laser treatment and massage and failed to find a difference in cervical range of motion, analgesic use per day, headache intensity per episode and number of headaches per day.[1143, 1220] A moderate-quality study that was a continuation of an earlier study evaluated high velocity low amplitude manipulation with laser and massage as placebo. They reported significant improvement in cervicogenic headache.[1151] A moderate-quality study evaluated manipulation versus exercise and found that exercise groups produced better long term outcomes than placebo or manipulation alone.[1219] High-amplitude, high-velocity manipulation is not recommended due to concerns it may increase risk of adverse effects such as arterial dissection.

Evidence: There are 4 high-[1099, 1118, 1137, 1138] and 76 moderate-quality RCTs or crossover trials (one with two reports) incorporated into this analysis.[487, 1096, 1097, 1100, 1101, 1106, 1110, 1111, 1113-1116, 1119-1131, 1139-1189] There are 25 low-quality [1190-1216] RCTs and 5 other studies [1117, 1214, 1216-1218] in Appendix 1.

A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: manipulation and mobilization, disorder terms-cervicalgia, neck pain, cervical pain, neck, cervical, vertebrae, vertebral, spine, radiculopathy, radiculopathies, radicular pain, intervertebral disc displacement, herniated, herniat*, displacement, displacements, displaced, disk, disc, disks, discs, pain, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Non-experimental Studies. In PubMed we found and reviewed 756 articles, and considered 130 for inclusion. In Scopus, we found and reviewed

1,436 articles, and considered 5 for inclusion. In CINAHL, we found and reviewed 134 articles, and considered 8 for inclusion. In Cochrane Library, we found and reviewed 32 articles, and considered 0 for inclusion. We also considered for inclusion 0 articles from other sources. Of the 143 articles considered for inclusion, 104 randomized trials and 13 systematic studies met the inclusion criteria.

Cervical Manipulation for Tension Headaches

Not Recommended.

Cervical manipulation is not recommended for tension headaches.[1140, 1145, 1149]

Strength of Evidence – **Not Recommended, Evidence (C)**

Level of Confidence – **Low**

Rationale: There is a moderate-quality study of 75 patients evaluating cervical manipulation versus laser light therapy and soft tissue massage as placebo. The authors did not find any benefit of manipulation after 19 weeks of follow up.[1140] Another moderate-quality study evaluated manipulation compared to amitriptyline for tension headaches. They found after discontinuation of treatment, manipulation had positive outcomes over amitriptyline; however, they did not address possible withdrawal headaches from amitriptyline.[1145]

Evidence: There are 4 high-[1099, 1118, 1137, 1138] and 76 moderate-quality RCTs or crossover trials (one with two reports) incorporated into this analysis.[487, 1096, 1097, 1100, 1101, 1106, 1110, 1111, 1113-1116, 1119-1131, 1139-1189] There are 25 low-quality [1190-1216] RCTs and 5 other studies [1117, 1214, 1216-1218] in Appendix 1.

A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: manipulation and mobilization, disorder terms-cervicalgia, neck pain, cervical pain, neck, cervical, vertebrae, vertebral, spine, radiculopathy, radiculopathies, radicular pain, intervertebral disc displacement, herniated, herniat*, displacement, displacements, displaced, disk, disc, disks, discs, pain, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Non-experimental Studies. In PubMed we found and reviewed 756 articles, and considered 130 for inclusion. In Scopus, we found and reviewed 1,436 articles, and considered 5 for inclusion. In CINAHL, we found and reviewed 134 articles, and considered 8 for inclusion. In Cochrane Library, we found and reviewed 32 articles, and considered 0 for inclusion. We also considered for inclusion 0 articles from other sources. Of the 143 articles considered for inclusion, 104 randomized trials and 13 systematic studies met the inclusion criteria.

Regular or Routine Manipulation or Mobilization

Not Recommended.

Regular or routine manipulation or mobilization, prolonged treatment (manipulation several times a month for years), and prophylactic treatment is not recommended.
Strength of Evidence – **Not Recommended, Insufficient Evidence (I)**
Level of Confidence – **High**

Rationale:	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:	There are 4 high-[1099, 1118, 1137, 1138] and 76 moderate-quality RCTs or crossover trials (one with two reports) incorporated into this analysis.[487, 1096, 1097, 1100, 1101, 1106, 1110, 1111, 1113-1116, 1119-1131, 1139-1189] There are 25 low-quality [1190-1216] RCTs and 5 other studies [1117, 1214, 1216-1218] in Appendix 1. A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: manipulation and mobilization, disorder terms-cervicalgia, neck pain, cervical pain, neck, cervical, vertebrae, vertebral, spine, radiculopathy, radiculopathies, radicular pain, intervertebral disc displacement, herniated, herniat*, displacement, displacements, displaced, disk, disc, disks, discs, pain, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Non-experimental Studies. In PubMed we found and reviewed 756 articles, and considered 130 for inclusion. In Scopus, we found and reviewed 1,436 articles, and considered 5 for inclusion. In CINAHL, we found and reviewed 134 articles, and considered 8 for inclusion. In Cochrane Library, we found and reviewed 32 articles, and considered 0 for inclusion. We also considered for inclusion 0 articles from other sources. Of the 143 articles considered for inclusion, 104 randomized trials and 13 systematic studies met the inclusion criteria.

Manipulation for Radicular Pain Syndromes with Acute Neurological Deficits

Not Recommended.

Manipulation is not recommended for the treatment of radicular pain syndromes with acute neurological deficits, especially with progressive neurological loss.

Strength of Evidence – **Not Recommended, Insufficient Evidence (I)**

Level of Confidence – **Moderate**

Rationale:

There is no quality evidence to address manipulation with neurological deficits; however, there are concerns about the use of manipulation in the presence of acute or progressive neurological deficits. Young et al. conducted an RCT evaluating cervical traction for radicular pain. Each group received manual therapy consisting of HLVA of the cervical and thoracic spine in addition to exercise. They reported improvement in both groups; however the study was not designed to evaluate the effects of manipulation of cervical radiculopathy.[1099] Another study compared cervical lateral glide mobilization to ultrasound and reported benefits for manipulation. The evaluations were taken immediately following the single intervention without long-term follow up.[1141]

Evidence:

There are 4 high-[1099, 1118, 1137, 1138] and 76 moderate-quality RCTs or crossover trials (one with two reports) incorporated into this analysis.[487, 1096, 1097, 1100, 1101, 1106, 1110, 1111, 1113-1116, 1119-1131, 1139-1189] There are 25 low-quality [1190-1216] RCTs and 5 other studies [1117, 1214, 1216-1218] in Appendix 1.

A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: manipulation and mobilization, disorder terms-cervicalgia, neck pain, cervical pain, neck, cervical, vertebrae, vertebral, spine, radiculopathy, radiculopathies, radicular pain, intervertebral disc displacement, herniated, herniat*, displacement, displacements, displaced, disk, disc, disks, discs, pain, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Non-experimental Studies. In PubMed we found and reviewed 756 articles, and considered 130 for inclusion. In Scopus, we found and reviewed 1,436 articles, and considered 5 for inclusion. In CINAHL, we found and reviewed 134 articles, and considered 8 for inclusion. In Cochrane Library, we found and reviewed 32 articles, and considered 0 for inclusion. We also considered for inclusion 0 articles from other sources. Of the 143 articles considered for inclusion, 104 randomized trials and 13 systematic studies met the inclusion criteria.

Manipulation for Radicular Pain Syndromes without Neurologic Deficits

No Recommendation.

There is no recommendation for or against manipulation for the treatment of radicular pain syndromes without neurologic deficits.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – **Low**

Rationale:	There is no quality evidence to address manipulation with neurological deficits; however, there are concerns about the use of manipulation in the presence of acute or progressive neurological deficits. Young et al. conducted an RCT evaluating cervical traction for radicular pain. Each group received manual therapy consisting of HLVA of the cervical and thoracic spine in addition to exercise. They reported improvement in both groups; however the study was not designed to evaluate the effects of manipulation of cervical radiculopathy.[1099] Another study compared cervical lateral glide mobilization to ultrasound and reported benefits for manipulation. The evaluations were taken immediately following the single intervention without long-term follow up.[1141]
Evidence:	There are 4 high-[1099, 1118, 1137, 1138] and 76 moderate-quality RCTs or crossover trials (one with two reports) incorporated into this analysis.[487, 1096, 1097, 1100, 1101, 1106, 1110, 1111, 1113-1116, 1119-1131, 1139-1189] There are 25 low-quality [1190-1216] RCTs and 5 other studies [1117, 1214, 1216-1218] in Appendix 1. A comprehensive literature search was conducted using multiple search engines including PubMed, Scopus, CINAHL and Cochrane Library without date limits using the following terms: manipulation and mobilization, disorder terms-cervicalgia, neck pain, cervical pain, neck, cervical, vertebrae, vertebral, spine, radiculopathy, radiculopathies, radicular pain, intervertebral disc displacement, herniated, herniat*, displacement, displacements, displaced, disk, disc, disks, discs, pain, controlled clinical trial, controlled trials, randomized controlled trial, randomized controlled trials, random allocation, random*, randomized, randomization, randomly; systematic, systematic review, retrospective studies, prospective studies, epidemiological studies, epidemiological research, and Non-experimental Studies. In PubMed we found and reviewed 756 articles, and considered 130 for inclusion. In Scopus, we found and reviewed 1,436 articles, and considered 5 for inclusion. In CINAHL, we found and reviewed 134 articles, and considered 8 for inclusion. In Cochrane Library, we found and reviewed 32 articles, and considered 0 for inclusion. We also considered for inclusion 0 articles from other sources. Of the 143 articles considered for inclusion, 104 randomized trials and 13 systematic studies met the inclusion criteria.

The main function of the thalamus is arousal and regulation [980, 1221]. Deep brain stimulation (DBS) attempts to stimulate the deep brain and thus arouse the patient and help the thalamus recover [980, 1222, 1223].

Deep Thalamic Stimulation

No Recommendation.

There is no recommendation for or against the use of deep thalamic stimulation in the treatment of TBI patients.

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. 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 (Thalamic Deep Brain Stimulation)); Traumatic brain injury OR Closed Head injury OR Penetrating Head Injury OR Concussion OR 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 12 articles in PubMed, 16 in Scopus, 5 in CINAHL, 1 in Cochrane Library, 2640 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 4 from Google Scholar, and 0 from other sources. Of the 5 articles considered for inclusion, 0 randomized trials and 4 systematic studies met the inclusion criteria.

Acupuncture

Acupuncture has been used to treat some patients with traumatic brain injury [1224, 1225]. It has be used to treat headache related symptoms in TBI patients [1225], muscle spasticity [1224], insomnia [1226] and cervical disorders. Cervical spine disorders are likely the most common indication for acupuncture among TBI patients.

Acupuncture is based in part on the theory that many diseases are manifestations of an imbalance between yin and yang, as reflected by disruption of normal vital energy flow (qi) in specific locations, referred to as meridians. Needling along one of the 361 classical acupuncture points on these meridians is believed to restore balance. This stimulation is classically done with thin, solid, metallic needles, which are frequently manipulated (or turned) manually or stimulated electrically (electroacupuncture). In addition to needling, acupuncture frequently involves moxibustion and cupping. Besides traditional Chinese acupuncture, there are many other types of acupuncture that have arisen, including accessing non-traditional acupuncture points.[1150, 1227-1231]

Acupuncture for Chronic Cervicothoracic Pain

Recommended.

Acupuncture is recommended for select use in chronic cervicothoracic pain with or without radicular symptoms as an adjunct to facilitate more effective treatments.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – **Low**

Indications:	As an adjunct treatment option for chronic cervicothoracic pain as a limited course during which time there are clear objective and functional goals that are to be achieved. Considerations include time-limited use in chronic cervicothoracic pain patients without underlying serious pathology as an adjunct to a conditioning program that has both graded aerobic exercise and strengthening exercises. Acupuncture is recommended to assist in increasing functional activity levels more rapidly, and, if it is recommended, the primary attention should remain on the conditioning program. In those not involved in a conditioning program, or who are non-compliant with graded increases in activity levels, this intervention is not recommended.
Benefits:	Modest reduction in pain.
Harms:	Rare needling of deep tissue, such as artery, lung, etc. and resultant complications. Use of acupuncture may theoretically increase reliance on passive modality(ies) for chronic pain.
Frequency/Dose/Duration:	Different frequencies and numbers of treatments used in quality studies ranged from weekly for 1 month to 20 appointments over 3 months. Usual program is 10 sessions over 3 to 4 weeks.[1232] An initial trial of 5 to 6 appointments is recommended in combination with a conditioning program of aerobic and strengthening exercises. Future appointments should be tied to improvements in objective measures to justify an additional 6 sessions, for a total of 12 sessions.
Indications for Discontinuation:	Resolution, intolerance, or non-compliance including non-compliance with aerobic and strengthening exercises.

Acupuncture for Acute or Subacute Cervicothoracic Pain

Not Recommended.

Routine use of acupuncture is not recommended for treatment of acute or subacute cervicothoracic pain or for acute radicular pain.

Strength of Evidence – **Not Recommended, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:

There are quality studies evaluating the utility of acupuncture for treatment of chronic cervicothoracic pain, although they conflict to some extent regarding whether it is efficacious and which type of acupuncture to perform. [1118, 1233-1235] One issue is the benefit of acupuncture versus electroacupuncture. A moderate-quality study showed that electroacupuncture was more effective than acupuncture alone.[1236] Quality trials compared to sham demonstrated a short term improvement in range of motion and pain[1233, 1234, 1237] and one of these moderate quality trials showed acupuncture was associated with improvements in pain-related activity, sleep, anxiety, depression, and satisfaction with life.[1232] Trials comparing acupuncture with no treatment have shown a decrease in pain of up to 40% over baseline after 12 weeks.[1238] The highest scored study (see evidence table) showed improvement in motion-related pain 1 hour after acupuncture above that seen for dry needling and sham acupuncture.[1233] Benefits beyond the duration of treatment of up to 3 years have been suggested.[1232] However, studies generally fail to control for attention bias, and also suggest that needling in locations other than traditional acupuncture points can provide equal benefit,[1232, 1239, 1240] which leads to questions regarding whether it is the needling rather than the acupuncture that was beneficial. Other quality trials have compared acupuncture with physiotherapy and medications and other treatments, with some failing to find differences in outcomes. A moderate-quality study of acupoint electrical stimulation did not find improvement in patients with variable duration of pain ranging from acute to chronic.[1241] Other studies found less of an effect or no effect, when compared to other treatments and placebo.[1118, 1237, 1242] One moderate-quality study looked at acupuncture compared to sham acupuncture; both treatment groups improved without a significant difference between the two up to 16 weeks after intervention.[1235]

There is no high quality evidence for treatment of acute cervicothoracic pain, radicular pain syndromes, or other cervical pain-related conditions. Acupuncture would not be expected to improve on the history of acute cervicothoracic pain treated with more effective treatments reviewed elsewhere.

Despite reservations regarding its true mechanism of action, the overall presence of quality trials demonstrating superiority of acupuncture to sham acupuncture provides quality evidence of efficacy, although the magnitude of benefits is modest and the treatment is passive. Acupuncture is minimally invasive, has relatively

low adverse effects in experienced hands, and is moderate cost depending on numbers of treatments.

There are no sham-controlled studies, but there is one quality study assessing use of acupuncture for treatment of spasticity related to TBI [1224] which suggested efficacy of electroacupunture at 100Hz. Acupuncture is not invasive, generally has negligble adverse effects, is moderate cost, and has some potential evidence of treatment efficacy for spasticity. There is no recommendation for treatment of spasticity related to TBI until there is a sufficient body 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: Acupuncture; Traumatic brain injury AND Closed Head injury AND Penetrating Head Injury AND Concussion AND 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 36 articles in PubMed, 30 in Scopus, 6 in CINAHL, 2 in Cochrane Library, 5460 in Google Scholar, and 1 from other sources. We considered for inclusion 5 from PubMed, 2 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 8 articles considered for inclusion, 2 randomized trials and 3 systematic studies met the inclusion criteria.

Biofeedback for TBI Patients

No Recommendation.

There is no recommendation for or against the use of biofeedback in the treatment of TBI patients.

Strength of Evidence – **No Recommendation, Insuffcient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There are no quality studies assessing Biofeedback for treatment of TBI. Biofeedback 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. There may be other indications for biofeedback.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Biofeedback OR neurofeedback; 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 17 articles in PubMed, 26 in Scopus, 4 in CINAHL, 3 in Cochrane Library, 3210 in Google Scholar, and 2 from other sources. We considered for inclusion 2 from PubMed, 1 from Scopus, 1 from CINAHL, 1 from Cochrane Library, 2 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 1 randomized trials and 5 systematic studies met the inclusion criteria.

Laser therapy or low-level laser therapy has been used for treating pain, inflammation, neurological disorders, and promoting healing of tissues [915, 1244-1249]. 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 [1244]. See Cervical and Thoracic Spine Disorders Guideline for indications for treatment of the cervical spine.

Laser Therapy/Low-Level Laser Therapy (LLLT)

No Recommendation.

There is no recommendation for or against the use of laser therapy in the treatment of TBI patients.

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. Low Level Laser Therapy is not invasive, has negligible adverse effects, is high cost, but has no evidence of treatment efficacy for 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: Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating Craniocerebral Trauma, Low level light therapy, low level laser therapy, Laser therapy, 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 120 articles in PubMed, 57 in Scopus, 1 in CINAHL, 0 in Cochrane Library, 1 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 2 articles considered for inclusion, 0 randomized trials and 1 systematic study met the inclusion criteria.

Functional electrical stimulation [1182] uses a stimulator to activate skeletal muscle to accomplish a functional goal [1250]. 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 [1251].

Functional Electrical Stimulation

No Recommendation.

There is no recommendation for or against the use of functional electrical stimulation in the treatment of TBI patients.
Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There are only two quality and one low quality study assessing Functional Electrical Stimulation for treatment of TBI [1252] [1253] [587] and 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 as it is lacking evidence of efficacy, there is no recommendation for treatment of TBI. As the low quality study was underpowered but suggested a trent towards meaningful differences, this rating is no recommendation rather than not recommended pending reports of further invetigations of quality.
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 [1182]; 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 33 articles in PubMed, 93 in Scopus, 5 in CINAHL, 11 in Cochrane Library, 14,000 in Google Scholar, and 0 from other sources. We considered for inclusion 3 from PubMed, 3 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 4 randomized trials and 2 systematic studies met the inclusion criteria.

Neuromuscular Electrical Stimulation (NMES)

No Recommendation.

There is no recommendation for or against the use of neuromuscular electrical stimulation in the treatment of TBI patients.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**

Level of Confidence – **Low**

Rationale:	There are two quality studies assessing Neuromuscular Electrical Stimulation for treatment of TBI and they conflict, with one showing improved swallowing function [1259], while another showed no improvement [1260]. A low quality trial suggested efficacy [1261]. Neuromuscular Electrical Stimulation is not invasive, has low adverse effects, is moderate to high cost in aggregate, but as it is lacking 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; Traumatic brain injuryIntracranial 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, 31 in Scopus, 2 in CINAHL, 5 in Cochrane Library, 23 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 3 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 4 articles considered for inclusion, 3 randomized trials and 1 systematic studies met the inclusion criteria.

Non-Operative Therapeutic Procedures

Traumatic brain injuries lead to neurobehavioral impairments such as physical, psychologic, and behavioral challenges [1262]. 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 [419, 802, 1262-1267].

Behavioral Programs

Recommended.

Behavioral programs are recommended for use in the treatment of TBI patients.
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 [1267], while another study used web-based approaches [1266].
Indications for Discontinuation:	Resolution of symptoms, sufficient recovery to function, lack of compliance, reaching a clinical plateau.
Rationale:	There are no quality sham-controlled trials. The overall literature base has much heterogeneity in methods and interventions which preclude an evidence-based treatment recommendation. 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, are thought to be effective and necessary for recovery from some sequalae and thus are 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: 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 136 articles in PubMed, 288 in Scopus, 5 in CINAHL, 8 in Cochrane Library, 16400 in Google Scholar, and 2 from other sources. We considered for inclusion 5 from PubMed, 1 from Scopus, 2 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 2 from other sources. Of the 10 articles considered for inclusion, 6 randomized trials and 1 systematic study met the inclusion criteria.

Inpatient and Outpatient Rehabilitation Programs

There are numerous and diverse rehabilitation programs that have been developed. Some are inpatient, while some are outpatient [1268-1270]. Some are based in acute care facilities, while others rehabilitation facilities and still others specialize in TBI patients. 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 [1271]. Some programs focus on TBI while others may focus on an array of neurological and orthopedic conditions [1272]. 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 [1268, 1269, 1273].

Outpatient: Home and Community-Based Rehabilitation

Recommended.

Outpatient home and community-based rehabilitation is selectively recommended for TBI patients.
Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Moderate**

Indications:	Sufficient residual symptoms and/or signs of post 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:	Highly variable and depends on the clinical status, including symptoms, signs, functional deficits, rate of progress, need for individualized care (e.g., coaching), etc. Outpatient apointments are generally at least 2-3 times/week. With outpatient physical therapy services needs, appointments may be daily.
Indications for Discontinuation:	Sufficient recovery, end of healing, reaching a plateau, non-compliance, substances 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 so 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: 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 25 articles in PubMed, 69 in Scopus, 35 in CINAHL, 6 in Cochrane Library, 17400 in Google Scholar, and 0 from other sources. We considered for inclusion 5 from PubMed, 2 from Scopus, 2 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 9 articles considered for inclusion, 4 randomized trials and 1 systematic study met the inclusion criteria.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: Outpatient rehabilitation, services, traumatic, brain, injury, intracranial, closed, head, penetrating, concussion, 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 35 articles in PubMed, 13 in Scopus, 17 in CINAHL, 5 in Cochrane Library, 7340 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 7410 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria.

Inpatient: Comprehensive Integrated Interdisciplinary Rehabilitation

Inpatient comprehensive integrated interdisciplinary rehabilitation is selectively recommended for treatment of TBI patients.

Recommended.

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 mulitidiscipilnary and generally TBI inpatients are sufficiently severely affected to require multidisciplinary services. Most patients will have incurred severe TBI, but occasionally, patients with moderate TBI may also be benefited by these programs. Generally not used for chronic patients unless the TBI was severe and the patient is making functional gains not possible or substantially less likely in an outpatient setting.
Benefits:	Ongoing treatment targeting functional outcomes to improve the patient's overall prognosis. Improved likelihood of achieving goals including 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.
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 components of inpatient rehabilitation programs, but naturally 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, is thought to be quite effective and so is recommended for selective treatment of TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: multidisciplinary rehabilitation program, 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 78 articles in PubMed, 52 in Scopus, 9 in CINAHL, 4 in Cochrane Library, 8490 in Google Scholar, and 2 from other sources. We considered for inclusion 8 from PubMed, 0 from Scopus, CINAHL, Cochrane Library, and Google Scholar, and 2 from other sources. Of the 10 articles considered for inclusion, 4 randomized trials and 2 systematic studies met the inclusion criteria.

Residential Rehabilitation

Residential rehabilitation facilities are used for treatment of TBI patients [1275]. 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.

Residential Rehabilitation

Residential rehabilitation is selectively recommended for treatment of TBI patients.
Recommended.

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 so are recommended for selective treatment of TBI.
Rationale:	There are quality studies assessing Residential Rehabilitation for treatment of TBI. Residential Rehabilitation is not invasive have no adverse effects, are low cost, have evidence of treatment efficacy, and are/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: Residential Rehabilitation, Brain Injuries, Head Injuries, Closed, Penetrating, Brain Concussion, Craniocerebral Trauma, Traumatic Brain, 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, 32 in Scopus, 10 in CINAHL, 6 in Cochrane Library, 2500 in Google Scholar, and 0 from other sources. We considered for inclusion 1 from PubMed, 4 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 6 articles considered for inclusion, 0 randomized trials and 2 systematic studies met the inclusion criteria.

Supported living programs or long-term care residential services are used for patients that require long-term care or rehabilitation [1276, 1277]. These are generally less intensive than skilled nursing facilities.

Supported Living Programs

Supported living programs are selectively recommended for treatment of TBI patients.
Recommended.

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 (SLP) for treatment of TBI. SLP is not invasive, has significant risks of problems such as nosocomial infections, and is high cost. For select severe TBI patients, there may be no other practical alternative and thus skilled care SLPs are selectively recommended for some severe TBI patients.
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, SLP, Long-Term Care Residential Services, Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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 Scopus, 14 in CINAHL, 97 in Cochrane Library, 33760 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

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 [1278].

Skilled Nursing Facilities

Skilled nursing facilities are selectively recommended for treatment of TBI patients.
Recommended.

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.
Frequency/Dose/Duration:	N/A
Indications for Discontinuation:	Recovery sufficient to not require
Rationale:	There are no quality studies assessing Nursing Care 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 severe TBI patients, there may be no other practical alternative and thus skilled care facilities are selectively recommended for some severe TBI patients.
Evidence:	A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: nursing care facility, facilities, skilled nursing facilities, nursing care; 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 Scopus, 4 in CINAHL, 7 in Cochrane Library, 23 in Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

With TBI, rehabilitation may be helpful particularly for rehabilitating the patient toward the goal of return to work (RTW).

Occupational Rehabilitation

Occupational rehabilitation is selectively recommended for treatment of TBI patients.
Recommended.
Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – **Low**

Indications:	There are many indications. These include sufficient impairments to provide for mismatch between the patient's current capabilities and future job requirements. Also helpful for mismatches in ADLs. In some practice settings, occupational therapy rehabilitation concentrates on the distal limbs while physical therapy concentrates on torso and proximal limbs; if so, those are additional indications.
Benefits:	Improved functional recovery, recovery at a faster pace. Ability to RTW. RTW at a higher job function. Return home with greater ability to perform ADLs.
Harms:	Negligible. Medicalization is possible.
Frequency/Dose/Duration:	Frequency is dependent on the individual status, including degrees of deficits, and degrees of mismatches between capabilities and ADLs and/or job tasks. In general, inpatient or outpatient intensive services requirements are often daily, while outpatient care with fewer mismatches may be as little as every week or two to start.
Indications for Discontinuation:	Recovery, plateau, lack of further functional gain, exhaustion of treatment options with quality efficacy.
Rationale:	There are no quality studies assessing the utility of Occupational Rehabilitation for treatment of TBI, although there are many studies of individual treatment components. Occupational Rehabilitation is not invasive, has negligible adverse effects, is moderate to high cost, has evidence of treatment efficacy for many component parts, and thus is 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: Occupational, rehabilitation, traumatic, brain, injury, intracranial, closed, head, penetrating, concussion, 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 239 articles in PubMed, 10 in Scopus, 7 in CINAHL, 2 in Cochrane Library, 21800 in Google Scholar, and 0 from other sources. We considered for inclusion 4 from PubMed, 1 from Scopus, 0 from CINAHL, 1 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 22058 articles considered for inclusion, 0 randomized trials and 5 systematic studies met the inclusion criteria.

Opioid/Chemical treatment programs have been used for treatment of substances use patients [1279-1281]. 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 [1282].

Opioid/Chemical Treatment Programs

Opioid/chemical treatment programs are selectively recommended for treatment of TBI patients.
Recommended.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Moderate**

Indications:	Substances 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 substances 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 Program for treatment of TBI patients. Opioid/Chemical Treatment Programs 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 TBI patients, but are likely effective for select patients with substances abuse and are thus recommended for treatment of select TBI patients.
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, 121 in Scopus, 11 in CINAHL, zero in Cochrane Library, 180 in Google Scholar, and zero from other sources. Zero articles met the inclusion criteria.

Outpatient Rehabilitation Services

See physical therapy, occupational therapy, vocational rehabilitation, outpatient treatment programs, etc.

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 [1283, 1284].

Music Therapy

There is no recommendation for or against the use of music therapy in the treatment of TBI patients.
No Recommendation.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There is one moderate quality study assessing Music Therapy for treatment of TBI [1284], however the sample sizes are so small at 4-5 per group that with non-significant results, the overall evidence base is inadequate. Music Therapy is not invasive, has no adverse effects, is low to moderate cost 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: Traumatic brain injury, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating Craniocerebral Trauma, Music Therapy, 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 articles in PubMed, 6 in Scopus, 0 in CINAHL, 2 in Cochrane Library, 24000 in Google Scholar, and 2 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 2 from other sources. Of the 4 articles considered for inclusion, 1 randomized trial and 1 systematic studies met the inclusion criteria.

Adaptive Devices

Orthotics, especially ankle-foot orthotics (AFOs) have been used for treatment of foot drop [1285].

Ankle-foot Orthotics for Treatment of Foot Drop

Ankle-foot orthotics are selectively recommended for treatment of foot drop associated with TBI injuries.

Recommended.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Rationale:	Although there are no quality trials, ankle-foot orthotics for foot drop have been used successfully for many years and thus they are recommended since they facilitate walking ability. Evaluation for orthotics should include evaluation of the footwear that is to be worn by the patient, including the nature of the fore-soles. Fronts of shoes and boots can catch on carpets and low-lying irregular surfaces, and modifications of shoes and boots may mitigate slip, trip, and fall risks posed by footwear.
Evidence:	There is 1 low-quality RCT in Appendix 1 [1285].

Adaptive devices, casting, and orthotics have long been used for treatment of impairments, including those related to TBI. This prominently includes AFOs for the foot and wrist/hand supports for the distal upper extremity.

Adaptive Devices, Casting, and Orthotics

Recommended.

Adaptive devices, casting, and orthotics are selectively recommended for treatment of TBI patients.

Strength of Evidence **– Recommended, Insufficient Evidence (I)**
Level of Confidence – Moderate

Indications:	Sufficient impairment to need a device to position the extremity for function, e.g., sufficient foot drop that a device may foster better walking and avoid stumbling; sufficient wrist drop that a device positions the extremity for better grasp. Some manufactured devices suffice, but some custom-made orthotics and casts are required to be made for specific circumstances or injury/patient characteristics.
Benefits:	Better able to use the extremity. May help maintain, or reduce losses of, extremity strength through greater use of the extremity.
Harms:	May use the device beyond that required, i.e., pseudo-dependent on it.
Indications for Discontinuation:	Sufficient recovery to no longer require a device
Rationale:	There are no quality studies assessing Adaptive Devices for treatment of TBI. See also Ankle/Foot 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: Adaptive devices (beds, standing

frames, wheelchair cushions, lower extremity bracing); 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 zero articles in PubMed, 533 in Scopus, zero in CINAHL, zero in Cochrane Library, 5 in Google Scholar, and zero from other sources. Zero articles met the inclusion criteria.

A comprehensive literature search was conducted using PubMed, Scopus, CINAHL, Cochrane Library, and Google Scholar without date limits using the following terms: muscle tone and joint restriction management, spasticity, orthotics, casting, postural control; 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, 71 in Scopus, 8 in CINAHL, 2 in Cochrane Library, 180 in Google Scholar, and 7 from other sources. We considered for inclusion 5 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 7 from other sources. Of the 12 articles considered for inclusion, 3 randomized trials and 1 systematic study met the inclusion criteria.

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

No Recommendation.

There is no recommendation for or against the use of neuromuscular re-education in the treatment of TBI patients.
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. Neuromuscular Re-Education is not invasive, has minimal adverse effects, is moderate to high cost in aggregate, but 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: 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 Scopus, 2 in CINAHL, 11 in Cochrane Library, 359 in Google Scholar, and 0 from other sources. We considered for inclusion 0 from PubMed, 0 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Zero articles met the inclusion criteria.

Muscle Tone and Joint Restriction Management

Severe damage to the central nervous system, of various origin, often causes severe spasticity [1286-1293].

Muscle Tone and Joint Restriction Management

There is no recommendation for muscle tone and joint restriction management in TBI patients.
No Recommendation.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

Rationale:	There are no quality studies assessing Muscle Tone and Joint Restriction Management (Including Spasticity) for treatment of TBI. There are other evidence-based recommendations for management of spasticity, occupational therapy, exercise, physical therapy, etc. Muscle Tone and Joint Restriction Management (Including Spasticity) is not invasive, has neglible adverse effects, is moderate to high cost in aggregate, but absent 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: postural balance, balance, balancing, visual, orthoptics, neurotology, neuro-otologic, communication, swallowing, therapy, 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 2,088 articles in PubMed, 2,265 in Scopus, 106 in CINAHL, 862 in Cochrane Library, 149,518 in Google Scholar, and 0 from other sources. We considered for inclusion 6 from PubMed, 1 from Scopus, 0 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 0 from other sources. Of the 7 articles considered for inclusion, 3 randomized trials and 4 systematic studies met the inclusion criteria.

Anger Management Therapy

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 TBI patients [1294]. 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 [1295]. Patients with anger after undergoing TBI is complex, multifaceted problem that should be under estimated and should be observed as psychological adjustment in difficulty [1296].

Anger Management Therapy

Anger management therapy is selectively recommended for treatment of TBI patients.

Recommended.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**

Level of Confidence – **Low**

Indications:	TBI patients 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 [1294].
Rationale:	There are no quality studies. Anger management therapy is not invasive, has negligible adverse effects, is moderate cost in aggregate and while there is not quality evidence of efficacy, it is recommended for selective treatment of TBI patients with anger issues as there is little else to manage these problems.
Evidence:	**Anger Management** – 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, closed, head, penetrating, concussion, 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 Scopus, 3 in CINAHL, 3 in Cochrane Library, 24600 in Google Scholar, and 0 from other sources. We considered for inclusion 2 from PubMed, 0 from Scopus, 1 from CINAHL, 1 from Cochrane Library, 1 from Google Scholar, and 0 from other sources. Of the 24612 articles considered for inclusion, 1 randomized trials and 6 systematic studies met the inclusion criteria.

Suicide Prevention

TBI patients are susceptible to depression and suicide, thus suicide prevention has been included in some programs [745]. Scheduled telephone interventions have also been used for TBI patients with depressive symptoms [1297]. Neuropsychological impairments such as dysfunction of memory and speed of information processing are post-concussion symptoms that can cause significant psychosocial problems following TBI [567, 1298-1301].

Suicide Prevention

Suicide prevention is selectively recommended for treatment of TBI patients.
Recommended.

Strength of Evidence – **Recommended, Evidence (C)**
Level of Confidence – Low

Indications:	TBI 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 [745]. A trial also used a scheduled telephone intervention [1297].
Rationale:	One moderate quality trial suggested psychological treatment was successful in producing improvement in hope that persisted for 3 months. Suicide prevention training is not invasive, has negligible adverse effects, is moderate cost in aggregate, has evidence of effectiveness to reduce hopelessness and so is recommended for selective treatment of TBI patients with depressive symptoms, depression, with or without suicidal ideation.
Evidence:	A comprehensive literature search was conducted using PubMed and Google Scholar without date limits using the following terms: psychological therapy, psychological rehabilitation, suicide, depressive disorder, depression; 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 105 articles in PubMed, 1,250 in Google Scholar, and 6 from other sources. We considered for inclusion 6 from PubMed, 4 from Google Scholar, and 6 from other sources. Of the 16 articles considered for inclusion, 7 randomized trials and 9 systematic studies met the inclusion criteria.

Substance Abuse Counseling

Substance abuse counseling has been used as a preventive action to minimize substance abuse following a traumatic brain injury (TBI) [1282, 1302].

Substance Abuse Counseling

Recommended.

Substance abuse counseling is recommended for use in the treatment of TBI patients.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**

Level of Confidence – **Moderate**

Indications:	Illicit substance(s) use, substance(s) abuse, substance(s) involved in TBI event, and/or problematic substancces use.
Benefits:	Potential for reduced risk of future injury, reduced adverse health risks.
Harms:	Negligible
Rationale:	There are no quality studies with sufficient data reporting to support an evidence-based recommendation. 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 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, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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 articles in PubMed, 22700 in Google Scholar, and 14 from other sources. We considered for inclusion 3 from PubMed, 1 from Google Scholar, and 1 from other sources. Of the 5 articles considered for inclusion, 4 randomized trials and 1 systematic studies met the inclusion criteria.

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 [1303]. Community-based rehabilitation programs for people with a brain injury are diverse [1304]. 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 [1303].

Community-Based Life Goals

No Recommendation.

There is no recommendation for or against the use of community-based life goals in the treatment of TBI patients.

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. 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 based life goals, 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 9 articles in PubMed, zero in Scopus, 11 in CINAHL, zero in Cochrane Library, 60 in Google Scholar, and zero from other sources. We considered for inclusion 9 from PubMed, zero from Scopus, zero from CINAHL, zero from Cochrane Library, 1 from Google Scholar, and zero from other sources. Of the 10 articles considered for inclusion, 1 randomized trials and 9 systematic studies met the inclusion criteria.

Resistance-based Healthcare (Telehealth; Telemedicine)

See Initial Approaches to Treatment Guideline.

Home Healthcare

See Initial Approaches to Treatment Guideline.

Return to Work and Assessments

Return to work (RTW) is considered a major challenge for TBI affected patients [152, 570, 1305-1311], as it is for return to sports [351, 1312-1315] [308, 309, 1316, 1317] [1318] [570]. Most estimates are that less than 50% of moderate to severely affected patients achieve employment [1306, 1319], and one estimate was under 10% [1320]. 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 [1305]. Factors associated with higher RTW rates are unclear, but generally thought to include shorter hospital stay, and shorter rehabilitation stays [1321-1323] which would also appear likely confounded by injury severity, [1311], younger age , multiple body injuries and increased severity of TBI (Waljas 2014) yet, Glascow Coma Scale Scores have not been found predictive [1323-1326] nor have anxiety or depression [1311, 1321, 1326-1328].
Decision-making 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 [103, 105, 108, 109, 117]. 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 [105] [109].
Decision-making may also be potentially difficult as there are reported problems with effort on physical examination and/or neuropsychological evaluation [176] [125, 128]. It has been suggested that this is addressable through: [170] optimize expectations, (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. [176]

Return to Work

It is recommended workers are returned to work, generally earlier than later. [460]
Recommended.
Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Moderate**

Indications:

All TBI patients. The speed of return to usual work activities, if possible, is based on the patient's current cognitive and physical status as compared with the job's cognitive and physical demands. Mild TBI patients may generally be returned to work in some capacity immediately. Close follow-up can be utilized to adjust work activities as tolerated. RTW for those with safety critical jobs requirement exercising of judgment and/or executive demands beyond the current capacity may require added cautions about the speed of RTW.

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 [103] [105, 109]. Under-reporting of pre-injury symptoms is reportedly problematic [105, 109]. 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 [109]. 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 faster based on return to work earlier
Harms:	May result in some frustration if the job demands substantially exceed the patient's capabilities. Mismatches may require re-addressing.
Rationale:	There are no RCTs comparing early vs. delayed return to work. 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. There is one moderate-quality trial assessing whether the use of resource facilitation is helpful for RTW and found efficacy of those services; please see vocational rehabilitation section below [1305]. 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 the earlier a worker can RTW, generally the better and return to work is recommended. Return to work is non-invasive, has few adverse effects, is low cost, is likely quite effective and thus is recommended. RTW often requires 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: Traumatic Brain Injury, Return to work, Intracranial injury, Closed Head injury, Penetrating head injury, Concussion, Brain Concussion, Craniocerebral Injury, Craniocerebral Trauma, Closed Head Trauma, Penetrating Head Trauma, Penetrating 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 130 articles in PubMed, 205 in Scopus, 20 in CINAHL, 6 in Cochrane Library, 47,100 in Google Scholar, and 5 from other sources. We considered for inclusion 7 from PubMed, 4 from Scopus, 9 from CINAHL, 0 from Cochrane Library, 0 from Google Scholar, and 5 from other sources. Of the 25 articles considered for inclusion, 2 randomized trials and 5 systematic studies met the inclusion criteria.

Vocational Rehabilitation Programs

Vocational rehabilitation programs are selectively recommended for treatment of TBI patients.
Recommended.

Strength of Evidence – **Recommended, Insufficient Evidence (I)**
Level of Confidence – **Moderate**

Indications:	Many severe TBI patients and occasional moderate TBI patients. Vocational rehabilitation programs are generally more helpful for those with greater mismatch between current abilities and job cognitive and physical demands. See also Return to Work above.
Benefits:	Potential to improve faster based on earlier return to work
Harms:	Negligible other than program cost.
Frequency/Dose/Duration:	N/A
Rationale:	There are no quality RCTs comparing vocational rehabilitation programs to those treated without VR programs. There is one moderate-quality trial assessing whether the use of resource facilitation is helpful for RTW and found efficacy of those services. [1305]. Vocational rehabilitation programs are non-invasive, have negligible effects, are moderate cost, and are likely effective and thus are recommended. They often 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: vocational 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 71 articles in PubMed, 1565 in Scopus, 42 in CINAHL, 49 in Cochrane Library, 50 in Google Scholar, and 1 from other sources. We considered for inclusion 2 from PubMed, 6 from Scopus, 1 from CINAHL, 0 from Cochrane Library, 2 from Google Scholar, and 1 from other sources. Of the 12 articles considered for inclusion, 1 randomized trial and 8 systematic studies met the inclusion criteria.

Functional Capacity Evaluations

While most commonly used for evaluation of spine and extremity disorders, functional capacity evaluations have been used to assess TBI patients [1336]. 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 [1337]. 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.[1338-1340] 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.

FCEs for Traumatic Brain Injury Patients

Recommended.

FCEs are a recommended option for evaluation of disabling TBI sequelae where the information may be helpful to attempt to objectify worker capability, function, motivation and effort vis-à-vis either a specific job or general job requirements. There are circumstances where a patient with moderate to moderately-severe TBI is not progressing as anticipated at 6 to 8 weeks and 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 provider is comfortable describing work ability without an FCE, there is no requirement to do this testing.

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 patients primary difficulties.

FCEs for Chronic Disabling Cervical or Thoracic Pain

Recommended.

FCEs are a recommended option for evaluation of disabling chronic cervical or thoracic pain where the information may be helpful to attempt to objectify worker capability, function, motivation and effort vis-à-vis either a specific job or general job requirements. There are circumstances where a patient is not progressing as anticipated at 6 to 8 weeks and 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 provider is comfortable describing work ability without an FCE, there is no requirement to do this testing.

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.
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.[1341-1347] 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 TBI patients. 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. 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.[1348, 1349] 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 a 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 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).[1350-1352] 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[1353] and the quality of an FCE is believed to be heavily dependent on the skill, knowledge and experience of the FCE evaluator.[1354]

FCEs for Chronic Stable Cervicothoracic Pain or Post-operative Recovery

No Recommendation.

There is no recommendation for or against FCEs for chronic stable cervicothoracic pain or after completion of post-operative recovery among those able to return to work.

Strength of Evidence – **No Recommendation, Insufficient Evidence (I)**
Level of Confidence – **Low**

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.[1341-1347] 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 TBI patients. 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.

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.[1348, 1349] 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 a 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 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).[1350-1352] 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[1353] and the quality of an FCE is believed to be heavily dependent on the skill, knowledge and experience of the FCE evaluator.[1354]

FCEs for Acute Cervicothoracic Pain, Acute or Subacute Radicular Syndromes, or Post-Surgical Cervical or Thoracic Pain

Not Recommended.

FCEs are not recommended for evaluation of acute cervicothoracic pain, acute or subacute radicular syndromes, or post-surgical cervicothoracic pain problems within the first 12 weeks of the post-operative period.

Strength of Evidence – **Not Recommended, Insufficient Evidence (I)**
Level of Confidence – **High**

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.[1341-1347] 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 TBI patients. 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.

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.[1348, 1349] 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 a 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 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).[1350-1352] 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[1353] and the quality of an FCE is believed to be heavily dependent on the skill, knowledge and experience of the FCE evaluator.[1354]

Evidence:
Comments:

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.

Prognosis

The prognosis for TBI patients is naturally correlated with the severity of the TBI event [126, 453, 1355-1357] [429]. Markers for prognosis include durations of loss of consciousness and post-traumatic amnesia [453]. Military and civilian populations have been found to have few long-term sequella of TBI after accounting for PTSD [100, 133, 1358].

Psychological factors, psychiatric history, anxiety, depression, low social support, perception of adverse consequences of TBI, stress and low intelligence are widely reported risks for persistence of TBI symptoms, especially mild TBI [104, 127, 130, 132-135, 1359] [110, 131]. There is a reported propensity for a sizable proportion of those with mild TBI to exaggerate the duration and severity of symptoms, especially with secondary gain considerations that include workers compensation or litigation [126, 427]. 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 [124-126, 128].

Full recovery is expected after mild TBI [117, 126, 350, 1360] [114, 135, 349, 1357, 1361], with expected full recovery in 1 to 3 months [429] [106, 349, 427, 436, 1317, 1362]. By contrast, most improvements in moderate to severe TBI occur over the first 1 to 2 years, but may persist beyond and indefinitely particulary with severe injuries [95, 429, 449, 1355]. 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 [1363-1365] 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 health care provider 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 sequellae of TBI, less frequent followup 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 followups needed for complex and/or less stable patients.

Appendix 2: PICO Questions

P Workers and/or patients with hip pain/suspected hip osteoarthrosis
I Antibodies for evaluating hip pain
C Are antibodies superior to other screening and testing tools for hip pain?
O Identification of hip pain and/or differentiating inflammatory rheumatic disorders from hip osteoarthrosis

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 [1]

    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 [318]

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 [770]

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 [1182]

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

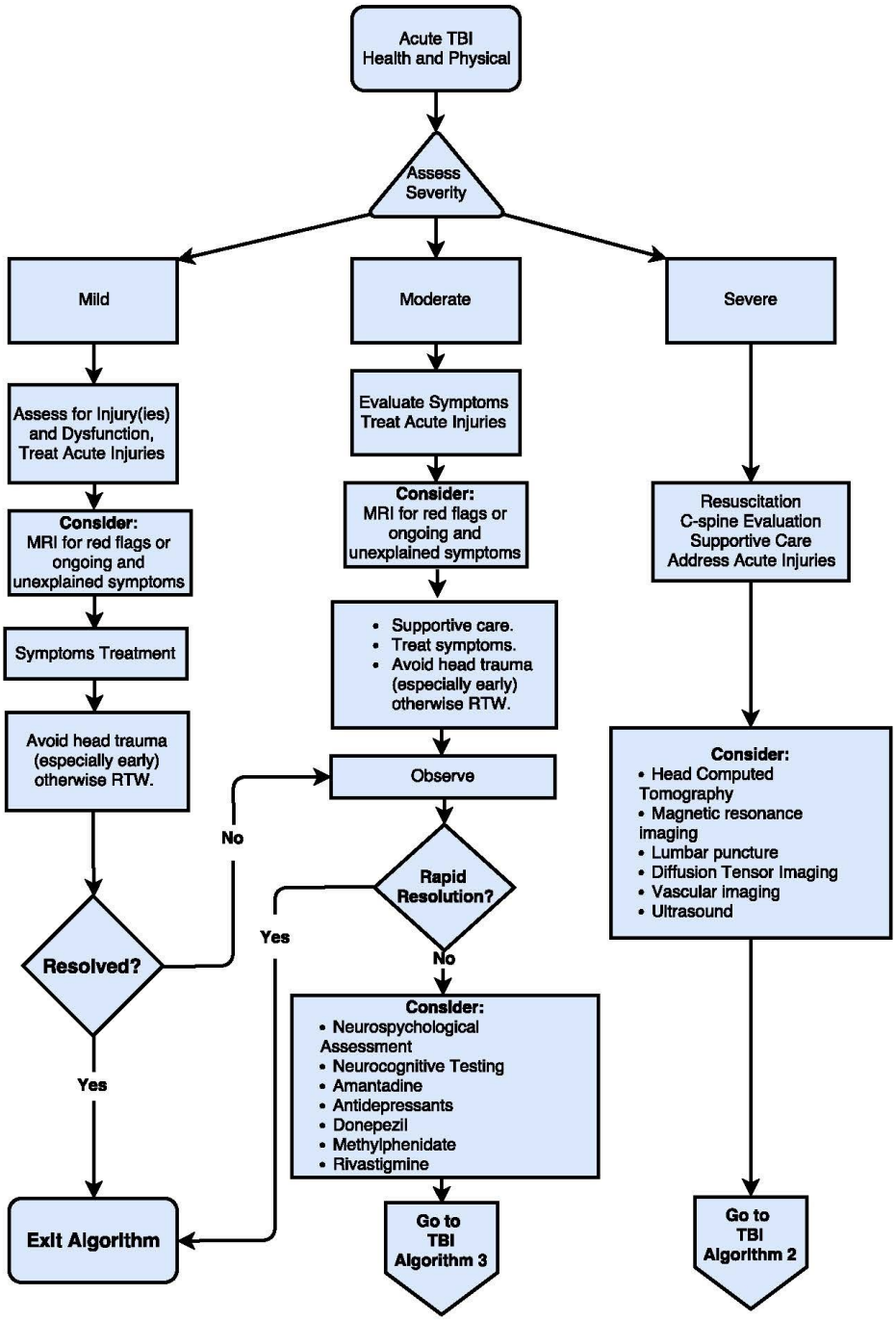
189. **P—**Workers and/or patients with TBI

I—Peer monitoring program

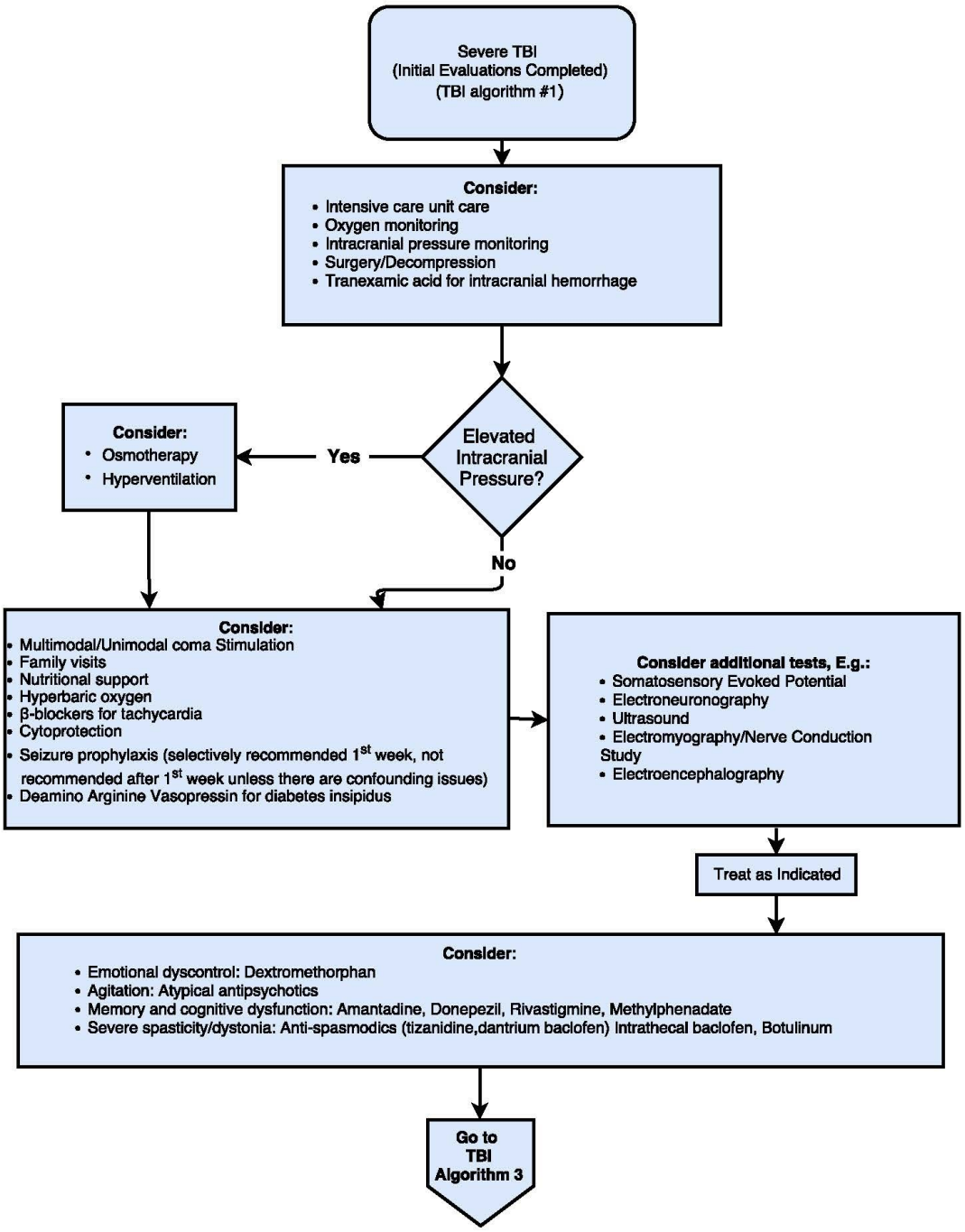
C—Is a peer monitoring program equivalent or superior to other effective treatments?

O—Treatment of TBI and/or symptoms

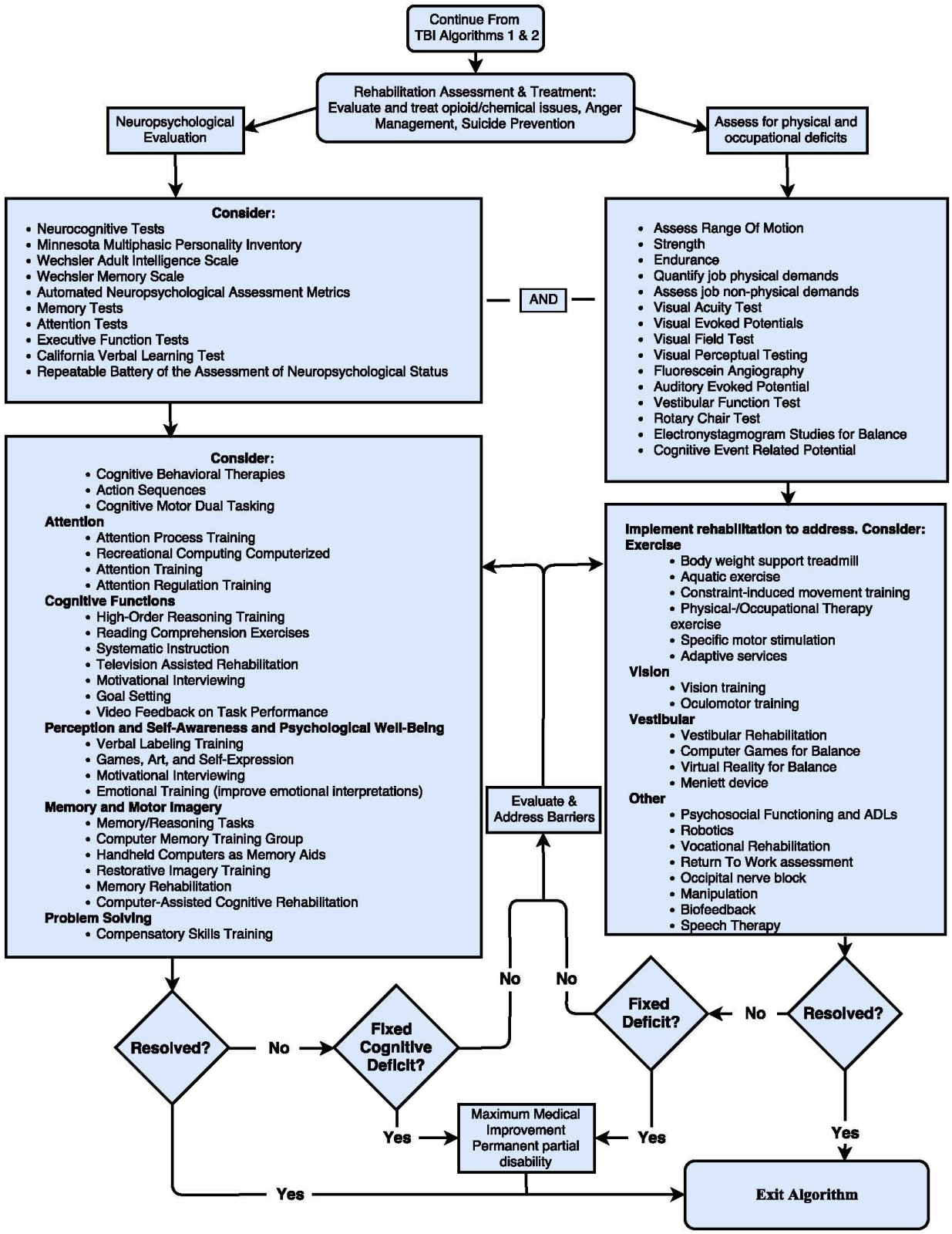
Algorithms



Algorithm 1. Acute TBI



Algorithm 2. Severe TBI



Algorithm 3. Rehabilitation Assessment and Treatment

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