

The Traumatic Brain Injury Continuum of Care

Rehab Education Lecture Series

Thursday, December 8, 2022

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1

Learning Objectives

1. Identify key assessments for Traumatic Brain Injury Categorization and understand prognosis based on this categorization.
2. Identify diagnosis complications and symptom management options from a medical perspective.
3. Demonstrate knowledge of referral patterns and treatment options for traumatic brain injury management.
4. Demonstrate knowledge of signs and symptoms that may complicate or prolong recovery.

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2

Agenda

- COURSE AGENDA (timeline):
- I. TBI Classification (30 min)
 - a. Definition
 - b. Predictors
 - c. Prevalence
 - d. Risk of untreated diagnostic pitfalls
-
- I. Pathophysiology of common symptoms (40 min)
 - a. Headache
 - b. Sleep
 - c. Fatigue
 - d. Mood
 - e. Dysautonomia
 - f. Sensory dysfunction
-
- I. Referral patterns and rehab trajectory (20 min)
 - a. Post Acute
 - b. Specialists
 - c. Worker's Compensation impact
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- I. Symptom Management and Chronic Medical Management (30 min)
 - a. Pacing

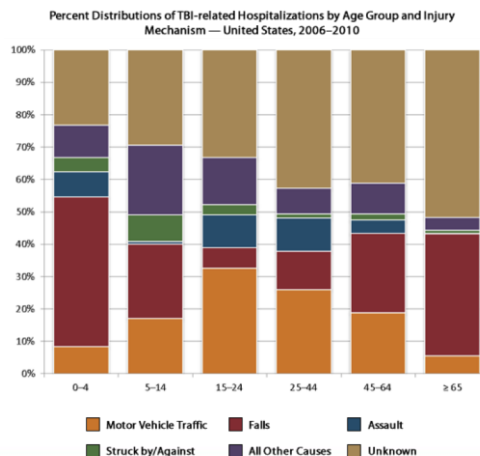
Definition of traumatic brain injury

- According to the National Head Injury Foundation
 - Traumatic head injury is **an insult to the brain**, not of a degenerative or congenital nature but **caused by an external physical force [to the head or body]**, that may produce a diminished or altered state of consciousness, which results in **impairments of cognitive abilities or physical functions**. It can also result in the **disturbance of behavioral or emotional functioning**. These impairments may be either **temporary or permanent** and cause **partial or total functional disability or psychosocial maladjustment**.

Prevalence and causes

- There were approximately 223,135 TBI-related hospitalizations in 2019* and 64,362 TBI-related deaths in 2020.¹
 - This represents more than 611 TBI-related hospitalizations and 176 TBI-related deaths per day.
 - These estimates do not include the many TBIs that are only treated in the emergency department, primary care, urgent care, or those that go untreated.²

1. Centers for Disease Control and Prevention. National Center for Health Statistics. Mortality Data on CDC WONDER. Accessed 2022. <https://wonder.cdc.gov/mort.html>.
2. Bell JM, Bresling MJ, DePadilla L. CDC's efforts to improve traumatic brain injury surveillance. *J Safety Res*. 2017;62:253–256.



<https://www.cdc.gov/traumaticbraininjury/data/tbi.html>

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5

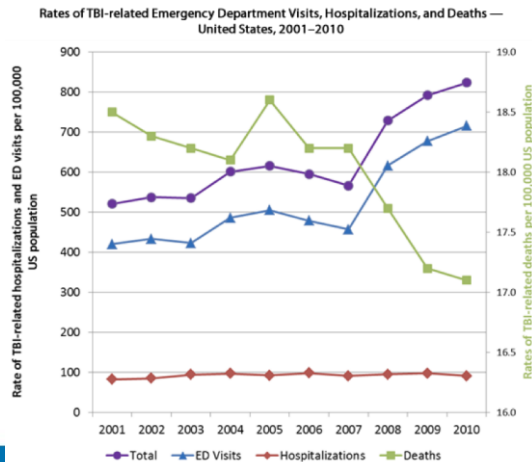
TBI Model Systems (1989-2011)

- “Model systems pool information and conduct research intended to improve the long-term functional, vocational, cognitive, and quality-of-life outcomes in individuals with TBI, SCI, or burn injury.”
 - ♦ Males > Females (2.5:1)
 - ♦ 16-25 yo, and >65 yo (bimodal age distribution)
 - ♦ Caucasian > African American > Hispanic > Asian
 - ♦ Single > married > divorced > widowed/separated
 - ♦ Education: 64% high school level or less
 - ♦ Employment: 62% employed at time of injury
 - ♦ Many injuries related to alcohol (46%), and increased risk of recurrence

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Effects



- According to the National Center for Injury Prevention and Control Statistics (2006)
 - 5.3 million people in the US with TBI related disability (2006)
 - Economic impact:
 - 60.4 billion in 2000
 - 76.5 billion in 2010
 - 80-90% of injuries are classified as mild

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TBI SEVERITY GRADING

Imaging positive?

-> Mild complicated or worse

Concussion is a type of mild TBI with no LOC or transient alteration of consciousness and no positive imaging correlates.

Classification System For Traumatic Brain Injury			
Classification	Duration Of Unconsciousness	Glasgow Coma Scale	Post-Traumatic Amnesia
Mild	<30 Minutes	13-15	<24 Hours
Moderate	30 Minutes-24 Hours	9-12	1-7 Days
Severe	>24 Hours	3-8	>7 Days

8

The Orientation Log (O-Log)

Key: 3=spontaneous/free recall
2=logical cuing
1=multiple choice, phonemic cuing
0=unable, incorrect, inappropriate

[illegible]

>25 on 2 consecutive days

Question	Error score	Notes
What is your name?	12	Must give both first name and surname.
Where were you born?	16	Must give day, month, and year.
Where are you now?	14	Town is sufficient.
Where are you from?	15	Must give actual town.
(a) City		
(b) Building	15	Usually in hospital or rehab centre. Actual name necessary.
Where were you admitted to this hospital?	18	Date.
How did you get here?	15	Mode of transport.
What is the first event you can remember after the day?	15	Any plausible event is sufficient (second answer).
Can you give some detail?	15	Any plausible relevant detail.
Can you describe the last event you can recall before the accident?	15	Any plausible event is sufficient (second answer).
What time is it now?	15	1 for each half-hour, etc.
What day of the week is it?	13	1 for each day, etc.
What day of the month is it? (i.e. the date)	13	1 for each day of month, etc.
What is the month?	15	1 for each month, etc.
What is the year?	20	10 for each year, etc.
Total Error		
1000 - total error		Can be a negative number.

76-100 = Normal
66-75 = Borderline
< 66 = Impaired

>75 on 2 consecutive days

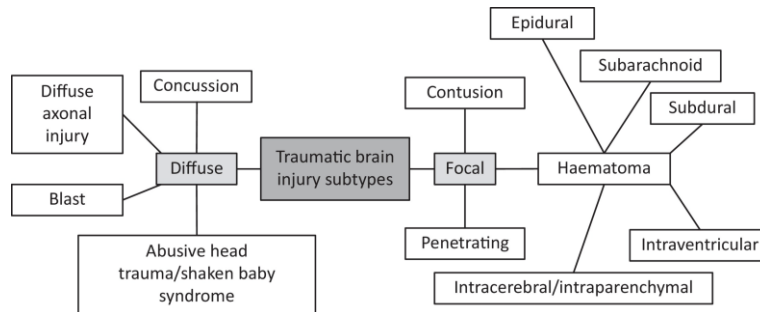
Rancho Los Amigos Levels of Cognitive Functioning

- Also known as Level of Cognitive Functioning Scale (LCFS)
- Worst score over past 24 hours
- Inter-provider communication tool

Level	Cognitive and behavioural description
I	Unresponsive to stimuli: no response
II	Generalised response: non-specific, inconsistent, and non-purposeful reaction to stimuli
III	Localised response: response directly related to type of stimulus but still inconsistent or delayed
IV	Confused-agitated: response heightened, severely confused, may be aggressive
V	Confused-inappropriate: some response to simple commands, but confusion with more complex commands; high level of distractibility
VI	Confused-appropriate: response more goal directed but needs cues
VII	Automatic-appropriate: response robot-like, judgement and problem-solving lacking
VIII	Purposeful-appropriate (with standby assistance): response adequate to familiar tasks, but subtle impairments require standby assistance with acknowledging other people's needs and perspectives, modifying plans
IX	Purposeful-appropriate (with standby assistance on request): responds effectively to familiar situations but generally needs cues to anticipate problems and adjust performance; low frustration tolerance possible
X	Purposeful-appropriate (modified) independently: responds adequately to multiple tasks but may need more time or periodic breaks; independently employs cognitive compensatory strategies and adjusts tasks as needed

TBI continuum

Concussion	Mild TBI	Mild complicated TBI	Moderate TBI	Severe TBI
----->Increased likelihood of focal damage				



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11



- Shock-wave injuries
 - Impact -> shock waves
 - Vibration/resonance of skull after impact -> bruising/contusions
- Acceleration/deceleration injuries
 - Antero-posterior deceleration (swings cerebrum on the brain stem, stretching/twisting)
 - Rotational acceleration (stretches connections b/w 2 hemispheres)

BRAIN INJURY

<http://tandfonline.com/bij>
ISSN: 0269-0952 (print); 1360-2818 (electronic)

Brain Inj. Early Online: 1-8
© 2016 Taylor & Francis Group, LLC DOI: 10.1080/02690952.2016.1192683

REVIEW ARTICLE

Traumatic brain injury: The first 15 milliseconds

Graham Martin

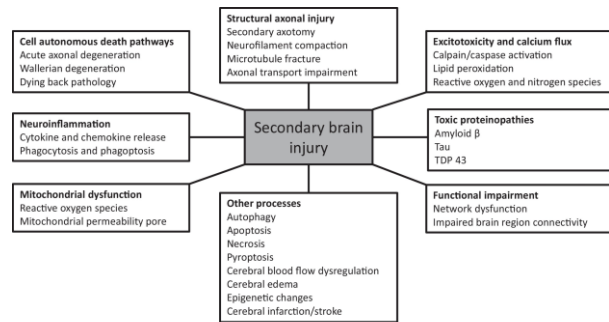
Accident Compensation Corporation of New Zealand, Wellington, New Zealand

12

SECONDARY INJURY

- Cascade of biochemical, cellular, and molecular events.

- Includes both **endogenous evolution of damage** within the brain + the effects of **secondary extracerebral insults** (hypotension, hypoxemia)



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13

COMBATING SECONDARY INJURY

- Prevention of secondary cerebral insults
 - ICU, pressure monitoring, etc
 - Optimization of autoregulation based on physiological parameters
 - Managing extra-cerebral insults (hypoxia, systemic inflammation, sodium imbalance, anemia)
 - Treatment of vasospasm if present
 - Early seizure prevention (AED x 7 days)
 - Dikmen SS, Temkin NR, Miller B, Machamer J, Winn HR. Neurobehavioral Effects of Phenytoin Prophylaxis of Posttraumatic Seizures. *JAMA*. 1991;265(10):1271–1277. doi:10.1001/jama.1991.03460100073027
- Neuro-protection
 - Translational research needed
 - Attempt to modulate secondary injury pathways
 - Ex. Minodoxil, cyclosporine, progesterone, statins, steroids. No benefit or detrimental.
 - Loane DJ, Faden AL. Neuroprotection for traumatic brain injury: translational challenges and emerging therapeutic strategies. *Trends Pharmacol Sci*. 2010 Dec;31(12):596-604. doi: 10.1016/j.tips.2010.09.005. Epub 2010 Oct 29. PMID: 21035878; PMCID: PMC2999530.
 - Nutrition:
 - Omega 3, B vitamins
 - If deficient: zinc, vit D, vit C
 - ? BCAAs or early ketosis

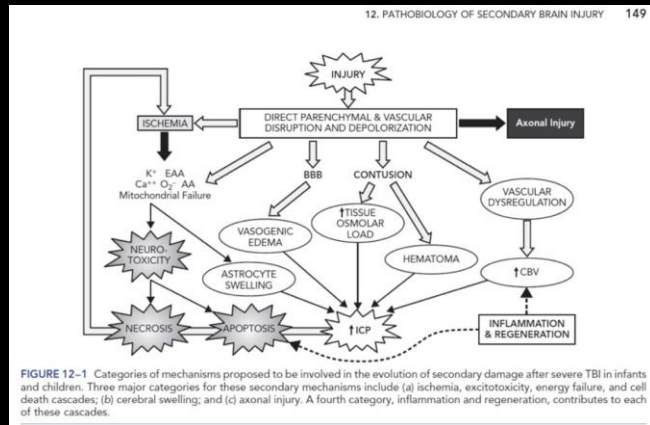
14

REVIEW

Neurochemical cascade of concussion

Matthew P. MacFarlane^{1,2} & Thomas C. Glenn^{1,2}¹UCLA Cerebral Blood Flow Laboratory, Los Angeles, CA, USA and ²Department of Neurosurgery, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

Secondary injury is also seen (pre-clinically) after a concussion.

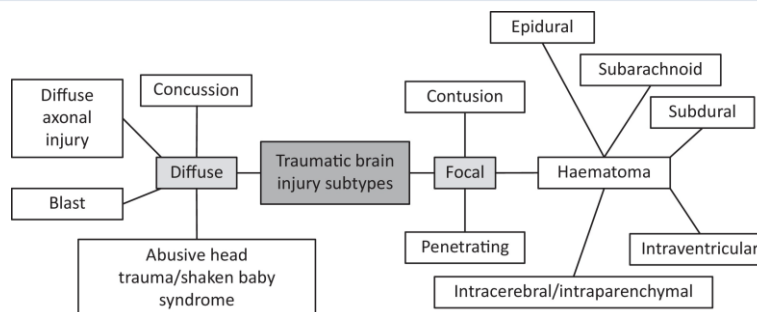


15

TBI continuum

Concussion	Mild TBI	Mild complicated TBI	Moderate TBI	Severe TBI
Diffuse injury ----->Increased likelihood of focal damage				

By definition & mechanism: ALL traumatic brain injuries are diffuse.



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16

ESTIMATING RECOVERY TIMELINE



Mild TBI --> days to weeks



Mild complicated to moderate TBI --> weeks to months



Severe TBI --> months to years

17

Disorders of consciousness

- Coma
- Unresponsive wakefulness ("vegetative state")
- Minimally conscious state (+ or -)
- JFK Coma Recovery Scale – Revised
 - 23 items that comprise six subscales addressing auditory, visual, motor, oromotor, communication and arousal functions.
 - Spanish, Italian, German, French, Dutch and Norwegian translations of the CRS-R are available.

18

GLASCOW OUTCOME SCALE

GOS	GOSE	Interpretation
1 = Dead	1 = Dead	Dead
2 = Vegetative state	2 = Vegetative state	Absence of awareness of self and environment
3 = Severe disability	3 = Lower severe disability	Needs full assistance in ADL
	4 = Upper severe disability	Needs partial assistance in ADL
4 = Moderate disability	5 = Lower moderate disability	Independent, but cannot resume work/school or all previous social activities
	6 = Upper moderate disability	Some disability exists, but can partly resume work or previous activities
5 = Good recovery	7 = Lower good recovery	Minor physical or mental deficits that affects daily life
	8 = Upper good recovery	Full recovery or minor symptoms that do not affect daily life

ADL = activities of daily living.

Cognitive Control/Function and Moderate-to-Severe Traumatic Brain Injury: Functional and Structural Brain Correlates - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Glasgow-outcome-scale-GOS-and-Glasgow-outcome-scale-extended-GOSE_tbl2_272176279 [accessed 2 Nov, 2022]

19

THRESHOLD VALUES

- Many relevant studies do not directly address issues of prognosis and have limited clinical utility.
- Threshold values are values of predictor variable above or below which a particular outcome was especially unlikely.
- Ex. Post traumatic amnesia for more than three months makes good recovery unlikely.

20

SYNOPSIS OF THRESHOLD VALUES

- MRI in first 2-8 weeks: depth of lesion is associated with worse outcome. Bilateral brainstem lesions = good recovery very unlikely.
- Initial CTH: presence of SAH, cisternal effacement, significant midline shift, EDH or SDH are all associated with worse outcomes however more specific conclusions cannot be drawn.
- Initial GCS: Lower scores associated with worse outcomes, but no specific conclusions can be drawn.
- Length of coma (as measured by time to follow commands): Good recovery unlikely if greater than 4 weeks. (Severe disability unlikely if less than 2 weeks - mixed data).
- Post traumatic amnesia: Severe disability unlikely if less than 2 months. Good recovery unlikely when greater than 3 months.
- Age: Good recovery after severe TBI unlikely if older than 65 (mixed data)

Zasler, et al. Brain Injury Medicine.

21

LET'S TALK CONCUSSION.

- **"It is time to stop using the term concussion as it has no clear definition and no pathological meaning.** This confusion is increasingly problematic as the management of 'concussed' individuals is a pressing concern. Historically, it has been used to describe patients briefly disabled following a head injury, with the assumption that this was due to a transient disorder of brain function without long-term sequelae. However, the symptoms of concussion are highly variable in duration, and can persist for many years with no reliable early predictors of outcome. **Using vague terminology for post-traumatic problems leads to misconceptions and biases in the diagnostic process, producing uninterpretable science, poor clinical guidelines and confused policy.** We propose that the term concussion should be avoided. Instead neurologists and other healthcare professionals should classify the severity of traumatic brain injury and then attempt to precisely diagnose the underlying cause of post-traumatic symptoms."

Sharp DJ, Jenkins PO. Concussion is confusing us all. *Practical Neurology* 2015;**15**:172-186.

The public is confused. Stop using the word concussion to describe all TBI or symptoms after a TBI.

22

"POST CONCUSSION SYNDROME"

- Still controversial nomenclature.
- "Persistent symptoms after ____" or
"Prolonged symptoms after ____"
- Having persistent symptoms > 3 months after a concussion is uncommon when considering the entire unselected population of people who sustain this injury.
- Cannot assume symptoms reported months to years later are directly associated with brain damage. Likely multifactorial comorbid factors, and rarely occurs without these factors.

Carroll LJ, Cassidy JD, Peloso PM, et al. Prognosis for mild traumatic brain injury: results of a WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med*. 2004;(suppl 43):84-105.

Zasler et al. *Brain Injury Medicine*. Conceptualizing outcome from mild traumatic brain injury. Pp 471-489

23

Original Investigation | Neurology

December 22, 2020

Association of Optical Coherence Tomography With Longitudinal Neurodegeneration in Veterans With Chronic Mild Traumatic Brain Injury

Casey S. Gilmore, PhD^{1,2}, Kelvin O. Lim, MD^{1,2,3}, Mona K. Garvin, PhD^{4,5}, et al

[Author Affiliations](#) | [Article Information](#)

JAMA Netw Open. 2020;3(12):e2030824. doi:10.1001/jamanetworkopen.2020.30824

Original Research | Published: 30 July 2020

Cerebral perfusion disturbances in chronic mild traumatic brain injury correlate with psychoemotional outcomes

Efrosini Papadaki , Eleftherios Kavroulakis, Katina Manolitsi, Dimitrios Makrakis, Emmanouil Papastefanakis, Pelagia Tsagaraki, Styliani Papadopoulou, Alexandros Zampetakis, Margarita Malliou, Antonios Vakis & Panagiotis Simos

Brain Imaging and Behavior. 15, 1438–1449 (2021) | [Cite this article](#)

364 Accesses | 5 Citations | [Metrics](#)

Journal of Neurotrauma > Vol. 37, No. 12 > Original Articles

Alterations in Plasma microRNA and Protein Levels in War Veterans with Chronic Mild Traumatic Brain Injury

Vikas Ghai, Shannon Fallen, David Barter, Kelsey Scherler, Taek-Kyun Kim, Yong Zhou, James S. Meabon, Aric F. Logsdon, William A. Banks, Abigail G. Schindler, David G. Cook, Elaine R. Peskind, Inyoul Lee, and Kai Wang 

org/10.1089/neu.2019.6826

Original Articles

Journal of Neurotrauma > Vol. 32, No. 16 > Original Articles

Abnormal White Matter Blood-Oxygen-Level-Dependent Signals in Chronic Mild Traumatic Brain Injury

Serguei V. Astafiev, Gordon L. Shulman, Nicholas V. Metcalf, Jennifer Rengachary, Christine L. MacDonald, Deborah L. Harrington, Jun Maruta, Joshua S. Shimony, Jamshid Ghajar, Mithun Diwakar, Ming-Xiong Huang, Roland R. Lee, and Maurizio Corbetta 

Published Online: 29 Jul 2015 | <https://doi.org/10.1089/neu.2014.3547>

Gait Performance in People with Symptomatic, Chronic Mild Traumatic Brain Injury

Douglas N. Martini , Lucy Parrington, Samuel Stuart, Peter C. Fino, and Laurie A. King

Published Online: 31 Dec 2020 | <https://doi.org/10.1089/neu.2020.6986>

24

Signs and Symptoms



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25

Physical Symptoms	Thinking/Memory	Emotions/Mood	Sleep
Headache	Confusion Disorientation	Irritability Loses temper	Sleeping more during daytime
Blurred or Double Vision	Loss of memory “amnesia”	Sadness or depression	Unable to fall asleep
Nausea or Vomiting	Blank stares Glassy eyed	More emotional	Unable to stay asleep
Dizziness	Poor attention span or concentration	Crying episodes	Sleep schedule change
Sensitivity to Light	Taking more time to think	Lack of motivation	Sleeping less hours per day
Sensitivity to noise or ringing in ears	Difficulty remembering recent events or new information	Nervous or anxious	Falling asleep suddenly during day
Tired or lack of energy	Unable to tolerate busy environments	Personality change	Extreme sleepiness
Unsteady or poor coordination	Feeling “in a fog” or “dazed”	Change in sexual drive	

26

Assessment tools

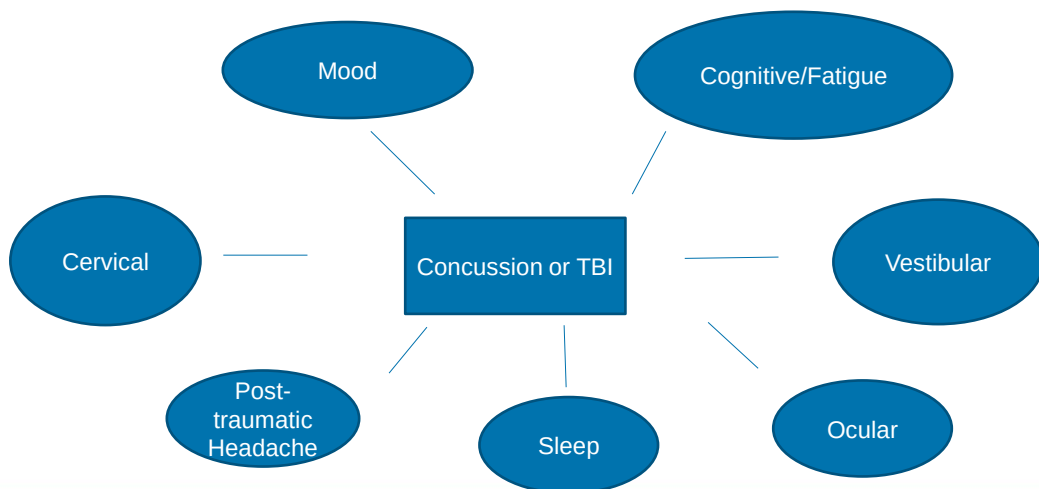
- Common Concussion symptom scales
 - Rivermead Post Concussion Symptoms Questionnaire (RPCS)
 - Post Concussion Symptom Scale (PCSS)
 - Graded Symptom Checklist (GSC)
 - Sports Concussion Assessment Tool – 5th edition (SCAT-5)
 - Concussion Symptom Inventory (CSI)
 - Post Concussion Symptom Inventory – Parent (PCSI-P)
 - Acute Concussion Evaluation
 - Health and Behavior Inventory (HBI)
- Pitfalls:
 - Using a "concussion" symptom scale for all TBIs
 - Do not fully capture the nature of subtype symptoms & associated conditions
 - Scores reflect the subjective burden of symptoms rather than providing objective values to trend.
 - EX. Headache consistently 6 does not capture frequency, intensity, duration, and type of headache.

Lumba-brown et al. Representation of concussion subtypes in common postconcussion symptom-rating scales. Concussion. Vol 4, No 3. 1 Nov 2019 <https://doi.org/10.2217/cnc-2019-0005>

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27

Identifying Primary Concussion or TBI Subtype



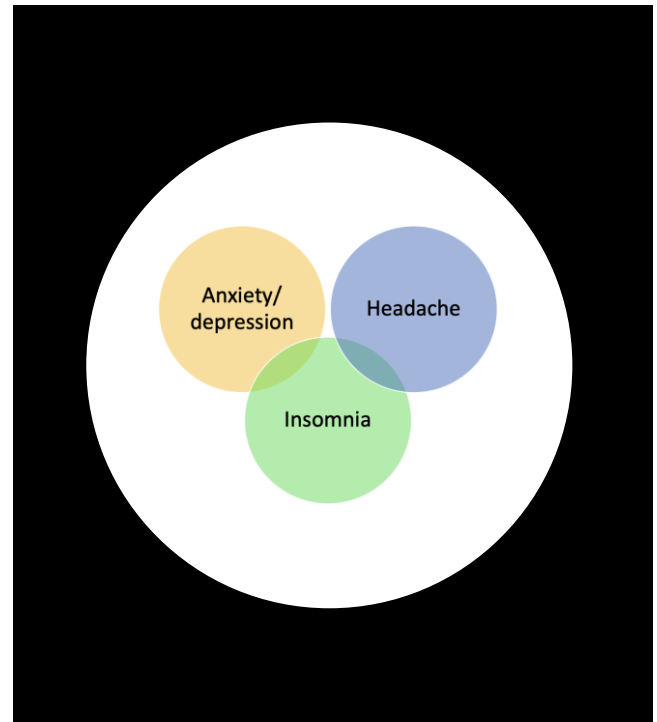
Reynolds et al. 2014

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28

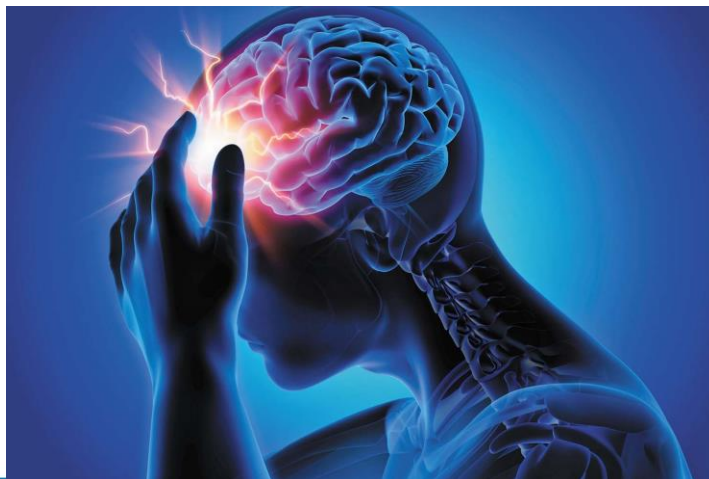
SYMPTOM-BASED TREATMENT

- Ontario Neurotrauma Foundation (ONF) recommends prioritizing:
 - If these are treated, can bring about improvement in other symptoms (fatigue, difficulty concentrating, irritability)



29

Headache

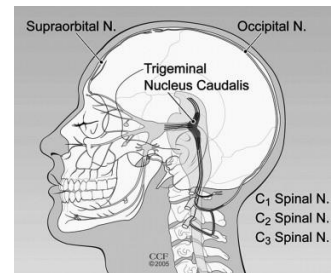


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30

Post traumatic headache

- **Intracranial:** The dura and venous sinuses are the most pain-sensitive intracranial structures.
- **Extracranial:** Skin, nerves, muscles, periosteum, sinuses, cervical joints/facets, TMJ.
- **Peripheral nociception:** Unmyelinated C and myelinated A Δ afferent neurons with bodies in DRG of upper 3 cervical segments -
> trigeminal nerve -> central pain processing pathways



Clinical approach to post traumatic headache (PTH)

- Classify type of headache based on International Headache Society classification.
- Migraine
- Tension
- Cervicogenic
- Neuralgia
- Cluster and paroxysmal hemicrania
- Medication overuse headache

PTH treatments

- Non-pharmacologic
 - Therapy
 - Modalities
 - Biofeedback
 - Cognitive Behavioral Therapy
 - Acupuncture
 - Massage
 - Chiropractic
 - Lifestyle modification
- Pharmacologic:
 - Topical analgesics
 - Abortive:
 - NSAIDs (< 8 days per month after 3 months)
 - Triptans
 - CGRP receptor antagonists
 - Muscle relaxers
 - Preventative
 - Beta blockers
 - Calcium channel blockers
 - Antidepressants
 - Anticonvulsants
 - CGRP receptor antagonists
 - Injections
 - Nerve blocks
 - Botox for chronic migraine
 - Trigger point injections

Red Flags

- Slow venous bleed/SDH: Progressive worsening in headache with or without new neurological deficits.
- Obstructive Hydrocephalus: Rare. Headache, nausea, vomiting, papilledema, incontinence.
- Normal pressure hydrocephalus: gait disturbance, cognitive decline, incontinence. Headache is often late symptom.
- Tension pneumocephalus: ball-valve air entering subdural space (must differentiate from non-tension pneumocephalus), neurosurgical emergency.
- Low pressure headache: worse within 15 minutes of sitting or standing, improved with lying down
 - CSF leaks, shunt over drainage, lumbar puncture headaches, and syndrome of the Trephined
- Carotid cavernous fistulas (CCFs): decreased vision, conjunctival chemosis, external ophthalmoplegia, and proptosis.
- Cavernous sinus thrombosis (CST): headache + cranial nerve findings should be evaluated for CST.
- Carotid artery dissection (CAD): headache, unilateral pulsatile tinnitus, partial Horner's syndrome, amaurosis fugax (temporary loss of vision in ipsilateral eye).
- Ictal headaches: associated with seizures

Sleep



35

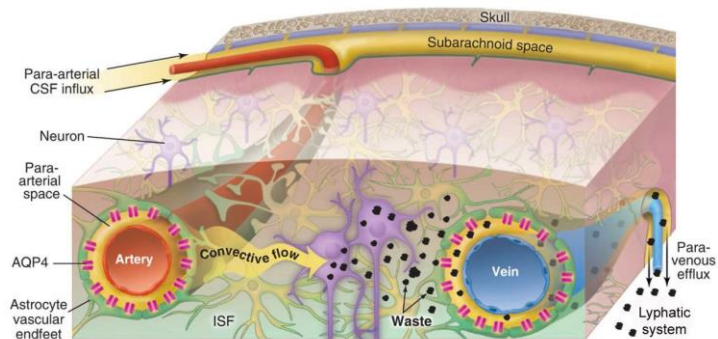
Purpose of Sleep

- **Restoration of biochemical/cellular substrate**
 - Depleted substrate are replenished during sleep
 - Slow Wave Sleep is associated with the release of Growth Hormone - promoting protein synthesis, anabolism, and cell repair
 - Potential immune system enhancement
- **Restoration of Synaptic Integrity and Responsiveness**
 - Restoration of neurotransmitters (repletion of depleted aminergic and cholinergic substrates)
 - Restoration of synaptic integrity (receptor sensitivity)
- **Sleep Facilitates the Process of Memory/Learning**
 - Info storage, organization, and coordination for future recall, and integration with other stored data

36

Glymphatic system

- So named due to dependence on glial cells (non-neuronal support cells) and similarity in function to the lymphatic system
 - Note: the brain does have conventional lymphatic vessels (dural sinus and meningeal)
- CSF → arterial paravascular space → CSF + interstitial fluid + parenchymal solutes → venous system
- Helps recycle the parenchymal space
- **Increases during Slow Wave Sleep**



<https://svn.bmj.com/content/4/2/75>

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37

Memory and Recall

- Proposed association of sleep stages with memory and recall
- Non-REM (more specifically, Slow Wave Sleep):
 - Specific ordered replay of day's events (hippocampus to cortex)
 - Potentially facilitates organization, integration, and later recall.
- REM
 - Random replay of events
 - May enhance associations, new solutions and thus increasing creativity, innovation, and problem solving skills

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38

Sleep Disturbance after TBI

- Disruption of normal sleep by time after injury:
 - Acutely after injury which is related to injury severity
 - Chronic phase
- Categories of primary sleep disorders:
 - Insomnia
 - Difficulty in initiating or maintaining sleep
 - Hypersomnia
 - Excessive daytime sleepiness
 - Circadian Rhythm Sleep Disorders
 - Displacement of sleep from its original circadian pattern
 - Narcolepsy
 - Sleep-related Breathing Disorders

Prevalence of Sleep Disorder after TBI

- Overall, **50%** of people suffered from some form of sleep disturbance after a TBI and **25–29%** had a diagnosed sleep disorder (insomnia, hypersomnia, apnea)¹
- In another study, ~70% of patients with moderate to severe TBI patients in IPR were found to have disrupted nighttime sleep²

1. Mathias, J. L., and P. K. Alvaro. "Prevalence of sleep disturbances, disorders, and problems following traumatic brain injury: a meta-analysis." *Sleep medicine* 13.7 (2012): 898-905.

2. Makley, Michael J., et al. "Return of memory and sleep efficiency following moderate to severe closed head injury." *Neurorehabilitation and neural repair* 23.4 (2009): 320-326.

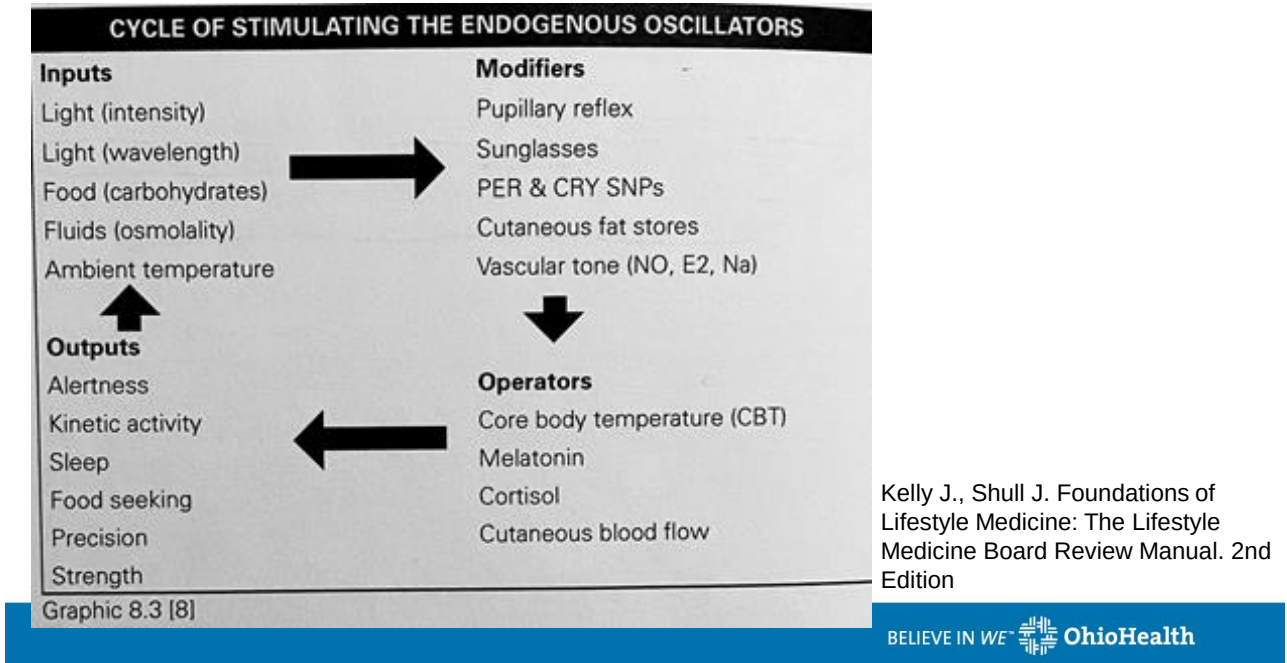
Associated problems with sleep disturbance

- Cognitive impairment
 - PTA clears as sleep efficiency improved
 - Poor attention and carryover
- Behavioral disruption
- Emotional changes
 - Elevated anxiety scores in those having difficulty initiating sleep
 - High depression scores in those difficulty staying asleep

Makley, Michael J., et al. "Return of memory and sleep efficiency following moderate to severe closed head injury." *Neurorehabilitation and neural repair* 23.4 (2009): 320-326.

Sleep treatments

- Non-pharmacologic
 - Lifestyle modification
 - Meditation
 - Mindfulness and gratitude
 - Biofeedback
 - Cognitive Behavioral Therapy-Insomnia (CBT-I)
- Pharmacologic:
 - Melatonin
 - Magnesium
 - Antidepressants
 - Hypnotics
 - Stimulants



43

Mood



44

Neuro-pathophysiology of mood after TBI

- Vulnerability of frontal/temporal/occipital lobes, corpus callosum, rostral brainstem and sub-frontal white matter to primary injury.
- Disproportionate effect of secondary injury on regions like the hippocampus.
- Neurotransmitter dysfunction (catecholamines, acetylcholine, serotonin)

Neuro-pathophysiology of mood after TBI

- Mood dysfunction is not due to one particular region or one particular neurotransmitter.
- Three major circuits contribute, employing multiple brain regions and neurotransmitter receptors:
 - Dorsolateral frontal-subcortical circuit
 - Lateral orbitofrontal-subcortical circuit
 - Anterior cingulate-subcortical circuit

Prevalence

- Roughly 50% of people develop a new axis 1 disorder after TBI (Koponen et al).
 - Most common diagnosis are **depression, substance use, and anxiety.**
- Can happen both with and without a personal or family history.
- Risk may be associated with severity.

Psychosis

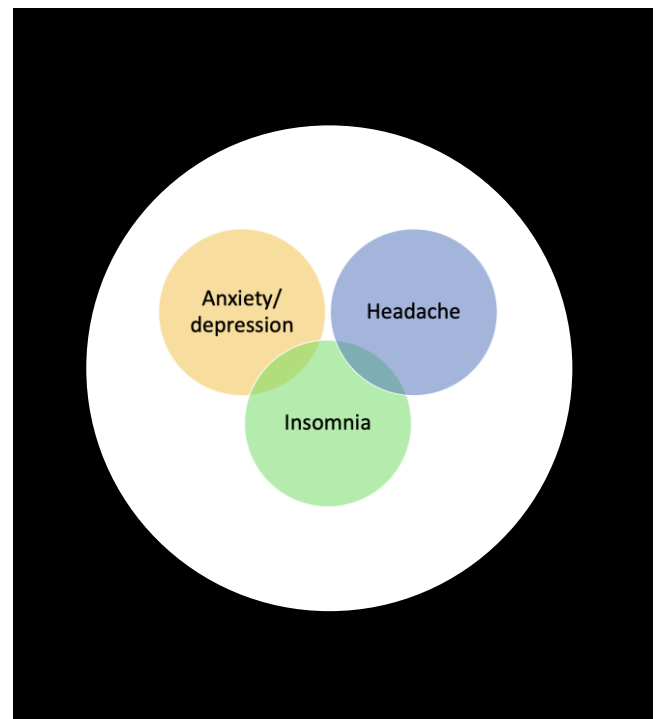
- Relatively rare complication after TBI.
- Patient's typically have a personal history or were otherwise predisposed (ex. Genetic predisposition, substance use, left-temporal epilepsy).
- While in the hospital, consider delirium.

Mood treatments

- Non-pharmacologic
 - Counseling
 - Many styles, may need to try different approaches or therapists.
 - Meditation
 - Mindfulness & gratitude
 - Biofeedback
 - Lifestyle (alcohol cessation, dietary considerations)
- Pharmacologic:
 - Antidepressants
 - Anxiolytics
 - Antipsychotics
 - Try to address multiple symptoms at once (sleep, pain, etc)

SYMPTOM-BASED TREATMENT

- Ontario Neurotrauma Foundation (ONF) recommends prioritizing:
 - If these are treated, can bring about improvement in other symptoms (fatigue, difficulty concentrating, irritability)



Cognitive dysfunction after TBI

- Irreversible
 - TBI
 - Genetic predisposition for dementia (ApoE4)
- Reversible
 - Headache
 - Pain
 - Mood disorder
 - Sleep disorder

51

Fatigue



52

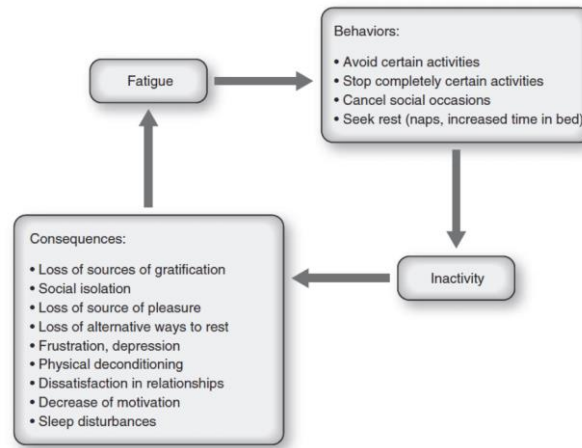
Post traumatic brain injury fatigue (PTBIF)

- Can have multifactorial causes OR occur in isolation
- No universally accepted definition
- Common
- Can happen at any degree of severity
 - More common to persist after severe TBI.

An awareness of a negative balance between available energy and the mental and physical requirement of activities.

PTBIF is NOT

- Chronic fatigue syndrome
 - Has several criteria + cognitive impairment and/or orthostatic intolerance
- Excessive daytime sleepiness (EDS):
 - EDS responds appropriately to rest.
 - Difficulty maintaining wakefulness.



Ripley et al, 2020

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PTBIF pathophysiology

- Central fatigue
 - Inability to maintain focused attention
- **Dysfunction of supratentorial structures involved in mentation**
- Peripheral fatigue
 - Impaired mobility and reduced exercise tolerance.
 - **Metabolic or physical limitation in muscle function.**

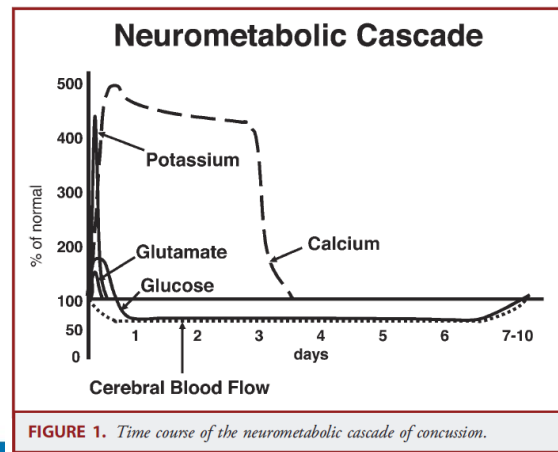
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PTBIF causes

- Multiple anatomic areas implicated
 - reticular activating system, ventromedial prefrontal cortex, corticostriatal network, frontocerebellar dissociation, white matter disruption
- Chronic metabolic depression
 - Initially after TBI, there's a hypermetabolic period followed by a state of chronic metabolic depression

Giza et al, 2014

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PTBIF is a diagnosis of exclusion

- Comorbidities to consider:
 - Medical issues
 - Medications
 - Sleep
 - Deconditioning
 - Neuroendocrine dysfunction
 - Mood disturbance
 - Genetics
- Evaluation:
 - Thorough history and examination
 - No universally accepted fatigue scale but there are several available.
 - Labs if indicated

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58

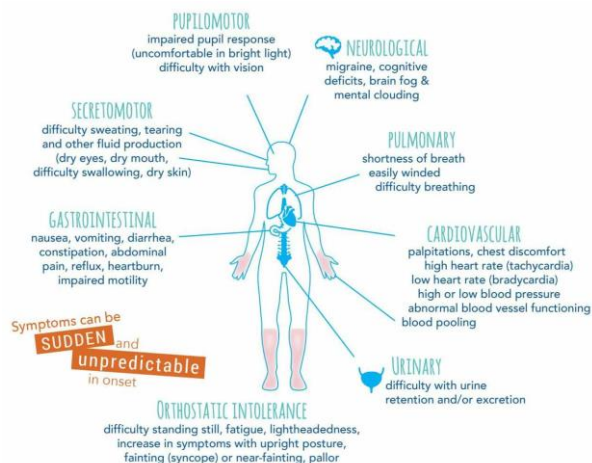
PTBIF treatments

- Non-pharmacologic
 - Pacing
 - Energy conservation
 - Sleep hygiene
 - Diet
 - Exercise (sub-symptom threshold)
 - ?blue light therapy
 - ?CBT
- Pharmacologic:
 - Stimulants
 - Activating antidepressants

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59

Dysautonomia



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60

Autonomic nervous system

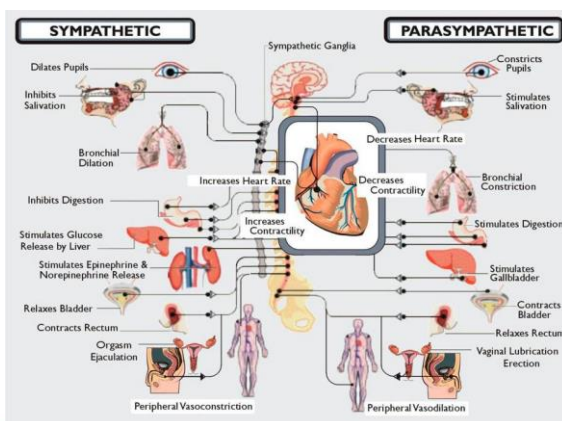
- Subconscious maintenance of body homeostasis in the face of daily challenges.
- Manages energy maintenance and organizes waste removal.

Sympathetic (fight or flight) + **parasympathetic** (rest & digest)

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Dysautonomia



- We think of dysautonomia in terms of peripheral effects
- The brain serves as an integration center that modulates ANS balance
- After injury, the brain's ANS response quality can be reduced.

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Paroxysmal sympathetic hyperactivity

- In complete disconnection, there is a loss of cerebral inhibition over a primarily excitatory drive.
- Can be seen in some cases of severe TBI

A Clinical feature scale (CFS) score

	0	1	2	3
Heart rate (beats per min)	<100	100-119	120-139	≥140
Respiratory rate (breaths per min)	<18	18-23	24-29	≥30
Systolic blood pressure (mm Hg)	<140	140-159	160-179	≥180
Temperature (°C)	<37.0	37.0-37.9	38.0-38.9	≥39.0
Sweating	Absent	Mild	Moderate	Severe
Posturing during episodes	Absent	Mild	Moderate	Severe

B Diagnosis likelihood tool (DLT): one point per feature present

Antecedent acquired brain injury
 Clinical features occur simultaneously
 Episodes are paroxysmal in nature
 Sympathetic over-reactivity to normally non-noxious stimuli
 Absence of parasympathetic features during episodes
 Features persist for >3 consecutive days
 Features persist for >2 weeks post-brain injury
 Two or more episodes daily
 Absence of other presumed causes of features
 Features persist despite treatment of alternative differential diagnoses
 Medication administered to decrease sympathetic features

C Interpretation of scores

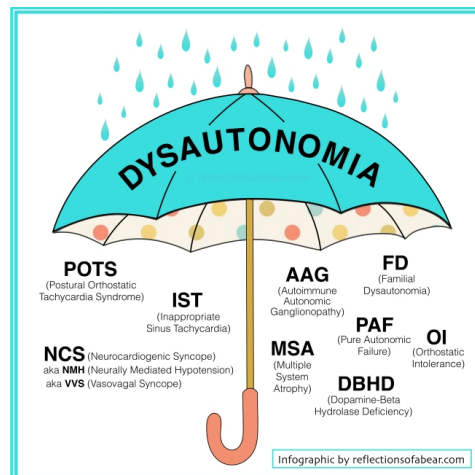
• **CFS subtotal**
 sum of CFS scores for each of the six features (0-3 points for individual features; maximum subtotal=18);
CFS subtotal severity scores:
 0=nil; 1-6=mild; 7-12=moderate; ≥13=severe
 • **DLT subtotal**
 sum of points for each feature present (one point per feature; maximum subtotal=11)
 • **PSH-AM**
 CFS subtotal + DLT subtotal;
PSH-AM score:
 <8=PSH unlikely; 8-16=PSH possible; ≥17=PSH probable

Meyfroidt et al, Lancet 2017

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Dysautonomia



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Orthostatic Intolerance

- NASA 10 minute lean test

Orthostatic Vital Signs/The NASA 10-minute Lean Test

	Blood Pressure (BP)		Pulse	Comments
	Systolic	Diastolic		
Supine 1 minute				
Supine 2 minute				
Standing 0 minute				
Standing 1 minute				
Standing 2 minute				
Standing 3 minute				
Standing 4 minute				
Standing 5 minute				
Standing 6 minute				
Standing 7 minute				
Standing 8 minute				
Standing 9 minute				
Standing 10 minute				



Dysautonomia treatments

- Non-pharmacologic
 - Hydration
 - Salt intake
 - Compression garments
 - Low impact exercise
 - Diet
 - Symptom directed therapies (ex. SLP for cognitive)
- Pharmacologic:
 - Beta blockers (ex. Propranolol)
 - Alpha 1 agonists (ex. Midodrine)
 - Steroid (ex. Fludrocortisone)
 - SSRI/SNRIs

Sensory Dysfunction



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Sensory dysfunction

- CN injury (special senses)
 - CN1 Olfactory Nerve
 - Most Common
 - Watchful waiting is treatment
 - Consider smell therapy
 - If ongoing > 12 weeks, likely permanent
- Visual and auditory processing
 - Theorized to be centrally mediated
 - Delayed processing
 - Sense of being overwhelmed with several simultaneous stimuli
 - Treatment options
 - Sensory modification
 - Neuro-optometry and Multi-sensory integration treatment
 - Bi-nasal occlusion
 - OSU Audiology has program for auditory processing program

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Other Considerations

Photosensitivity

- Sunglasses to minimize fluorescent and sun light intensity
- Sunvisors/Hats
- Blue Light Filters on phones and computers
 - Flux download on computers for bluelight filter
- Must Resensitize!
 - Reduce use to not increase chance of prolonged symptoms
 - Use table lamps vs overhead



Hyperacusis

- Environmental control
- Infrequent use of earplugs
 - When remove may make patient more hypersensitive to noise
- Gradual increase of auditory stimulation

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Referral patterns and Trajectories



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70

Referral Patterns and Considerations

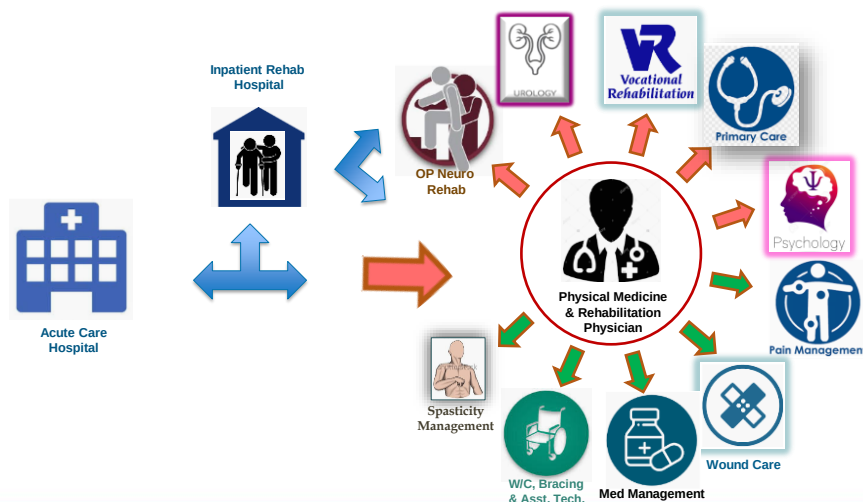
Acute Care to ???

Inpatient Rehab	Home Health	Outpatient
- Require > 2 disciplines - Insurance requirements = denials if cognition is only the impairment - CARF Accreditation - OHRH - OSU Dodd	- Have the appropriate supervision level - Unable to leave home	- OT/PT/SLP - Wheelchair and assistive technology clinic - DRIVE program - Linkage to Vocational Rehab

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Ideal State – PM&R Managing TBI Healthcare



Green: providing services
Pink: referring to services

Multimodal and multidisciplinary approach.

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72

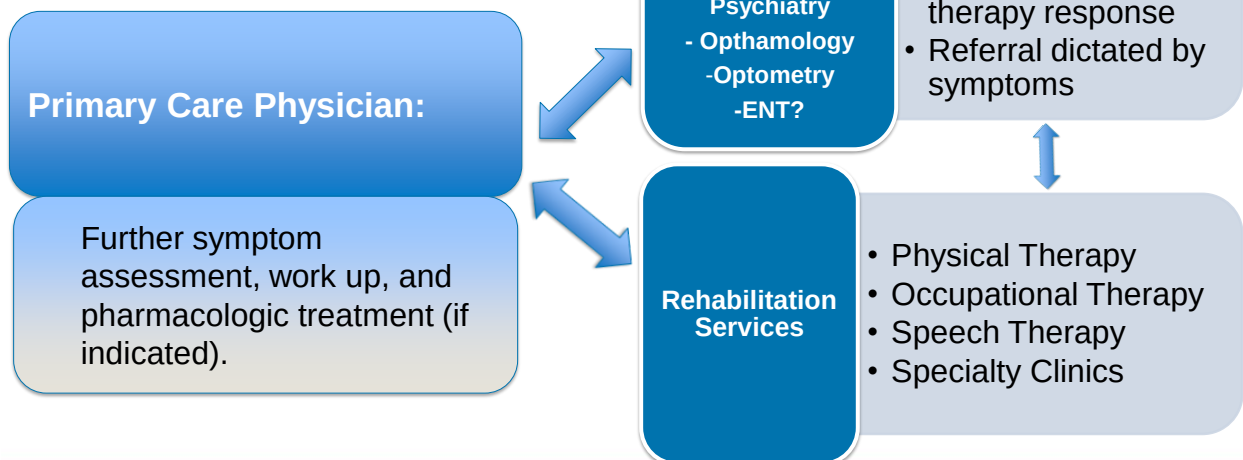
When to Refer and to Whom?

Most symptoms from a concussion resolve within 7-10 days, if still symptomatic involve the physician for diagnosis and referrals

- May have been categorized as concussion but has a more severe TBI

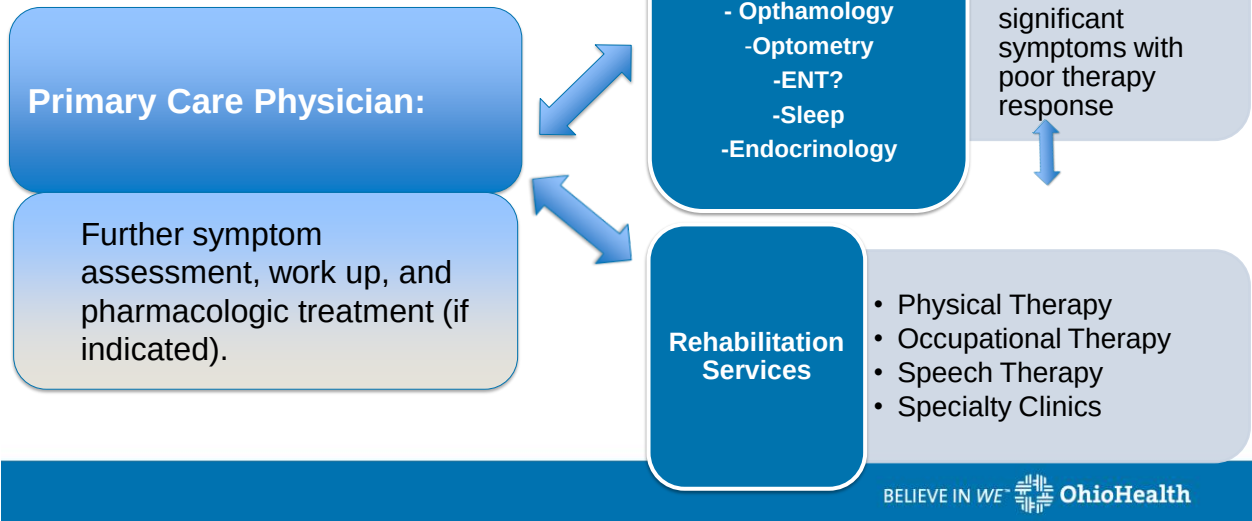
73

When to Refer and to Whom in Concussion and Mild TBI?



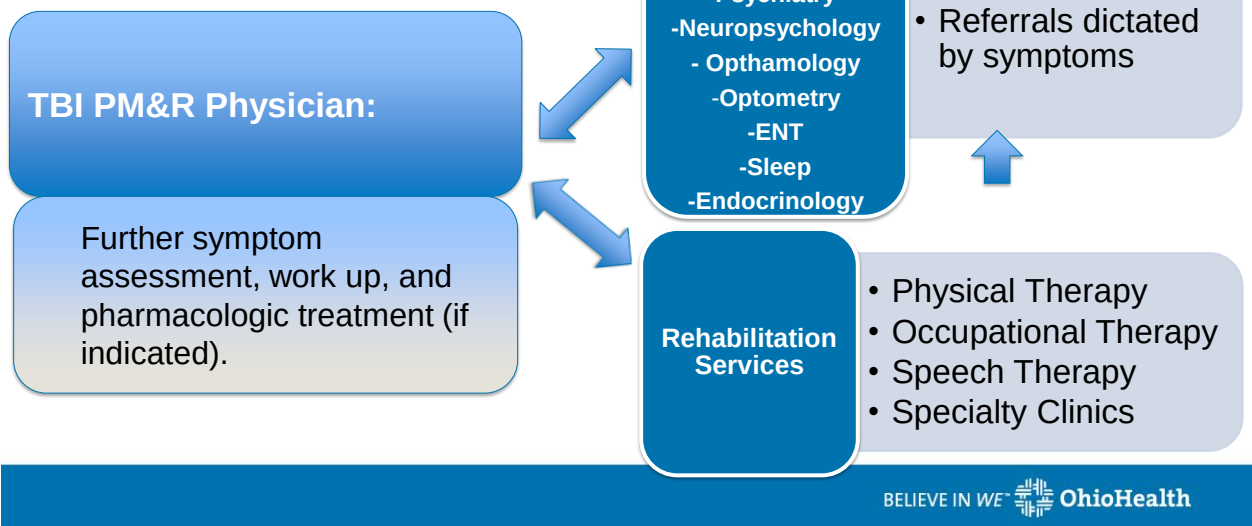
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When to Refer and to Whom in Mild Complicated and Moderate TBI?



75

When to Refer and to Whom in Severe TBI?



76

When to Refer and to Whom?

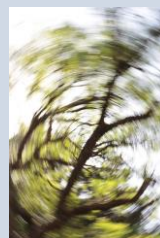
Neuropsychology

- Ongoing cognitive deficits with potential return to work
- Concern for medical contributions for cognitive symptoms
- Capacity Evaluation
- Consider practicality to “time to testing” (i.e. wait times)

When to Refer and to Whom?

Vestibular AND/OR Orthopedic physical therapy

- Positional Vertigo
- Dizziness
- Neck pain
- Headache
- Imbalance
- Motion Sensitivity



When to Refer and to Whom?

Occupational Therapy

- Visual-perceptual concerns
- UE Impairments
- Return to Driving concerns

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When to Refer and to Whom?

Speech Therapy

- Memory
- Communication
- Focused attention
- Sustained attention
- Selective attention
- Alternating attention
- Divided attention
- Executive function
- Problem solving and awareness



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80

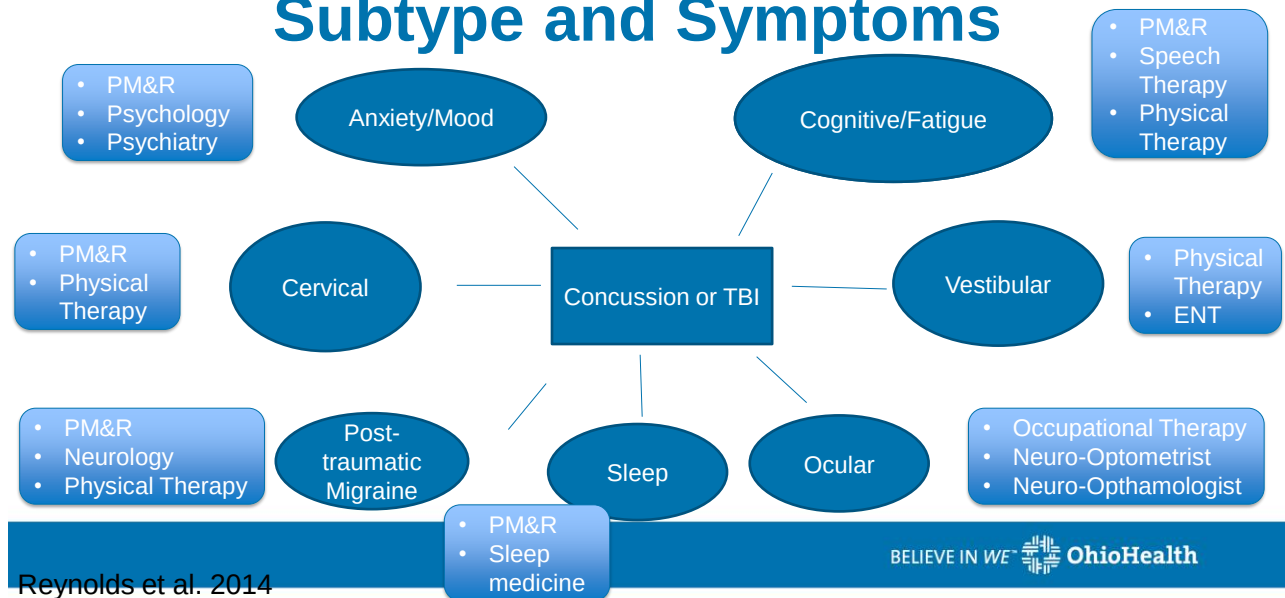
When to Refer and to Whom?

TBI specialist or Neurologist
• TBI PM&R sub-specialty • Dr. Mehta (RMH) • Can medically address all TBI sequelae • Neuro with headache sub-specialty • Dr. Natekar (GMC) • Dr. Hubert (Chatam Lane) • Dr. Shafqat (Berger) • Neuro with epilepsy sub-specialty • General Neuro also seeing TBI • Dr. Moneme (Chatham) • Dr. Eubank (Chatham) • Neuro for Movement Disorder (RMH) • Spasticity Referral • Mix of PM&R and Neuro providers

Neuro-optometrist
• Eye misalignment or binocular deficit • Photosensitivity • Visual fatigue • Headache stimulated by reading, TV, lights, and/or visual movement • Poor response to vestibular therapy or occupational therapy > 3-4 weeks

81

Referrals Suggested with Clinical Subtype and Symptoms



82

A row of various mobility devices is parked against a plain, light-colored wall. From left to right, there is a motorized wheelchair with a black frame and large rear wheels, a standard wheelchair with a black frame and large rear wheels, a folding chair with a black frame and large rear wheels, and a folding chair with a black frame and large rear wheels. The devices are arranged in a line, with the motorized wheelchair on the far left and the folding chairs on the right. The floor is a light-colored, polished surface.

[illegible]

Head
Head back, chin tucked, ears, shoulders, hips aligned.

Neck
Use headphones. Do not cradle phone between head and shoulder.

Elbows
At sides - slightly more than 90 degree bend.

Chair
Fully adjustable with lumbar support in small of the back.

Eyes
Level with top 1/3 of screen - 18-24"

Document Holder
Adjacent to and at same height as monitor.

Keyboard
Same height as elbow with arms slightly bent. Keyboard gently!

Mouse
Adjacent to and at same height as keyboard.

Chair Height
Has slighty more than 90 degrees, feet flat on the floor.

Take breaks every 30 minutes!

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Management of

Cognitive/Fatigue

- Pacing
- Sleep Management
- Orthostatic Hypotension Management
- Exertional training

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85

Activity Pacing vs. Rest

- “No evidence that complete rest ...improves or adversely impacts outcome after mTBI” (Silverberg et al 2013)
- Rest recommended 1-2 days
 - Physical/mental exertion = high energy demands with limited energy available
- Negative physiological consequences of rest evident after 3 days

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To Rest or Not to Rest?

Physical and/or mental exertion can exacerbate symptoms at any stage of recovery

Children and Adolescents may need longer recommended rest (Moser et al 2012)

Light activity within the first 7 days of concussion was associated with a decrease in likelihood of persistence symptoms at 28 days (Grool et al 2016)

Rest Defined

Cognitive Rest

- Avoid activities that require attention or concentration
- Avoid text messaging or video games
- Limit TV and computer use
- Limit reading

Physical Rest

- Avoid activities that exacerbate symptoms
- Avoid activities that increase already elevated heart rate
- Avoid aerobic exercise or weight lifting
- Avoid household chores/yardwork
- Avoid sexual activity

Sleep Management



Daytime Suggestions:

- Set an alarm to wake up at the same time every day, including weekends
- Limit watching TV
- If symptoms do not increase, it is okay to be active
- Regular daily exercise should be done at least 3 hours before going to sleep to allow your body to calm prior to attempting to fall asleep
- Limit daytime naps to less than 20 minutes
- If you have to nap, sleep before noon rather than later in the day to limit the interruption of your sleep/wake cycle

Sleep Management

Nighttime Suggestions:

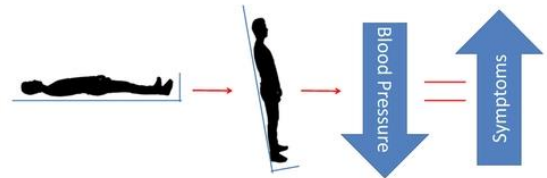
- Go to bed at the same time every night
- Follow a bedtime routine
- Perform calming activities 30 minutes prior to bedtime
 - Avoid stimulating movies, books, or exercise
 - Avoid eating heavy meals before bedtime
 - Listen to relaxing music
- Avoid alcohol and limit caffeine intake
- Use your bed only for sleep and intimacy
- If you are unable to sleep for 20-30 minutes...
 - Get up and do a calm activity
 - Return to bed once sleepy
 - Repeat this cycle until you fall asleep
 - Avoid lying awake in bed for long periods of time
- Minimize noise, light and temperature extremes during sleep
- Deep breathing, meditation or visualization can help



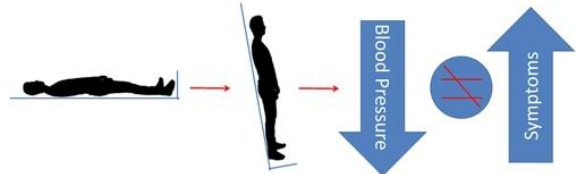
Orthostatic Hypotension

- **Testing:**
 - Measure supine BP and HR after patient resting comfortably for 5 minutes
 - Take patient to standing if safe
 - Take an immediate BP/HR measure
 - Take a BP/HR measure at 1 min
 - Take a BP/HR measure at 3 min
 - BP cuff must be held at the level of the right atrium
 - Holding below this level will result in a 5-10 mm Hg underestimation of BP

Traditional Perception of Orthostatic Hypotension



Revised Perception of Orthostatic Hypotension



Orthostatic Hypotension Definitions

- **Orthostatic Hypotension/Postural Hypotension**
 - Sustained reduction in systolic BP of 20 mm Hg or diastolic BP of 10 mm Hg within 3 min of standing or during a head-up tilt at 60 degrees
- **Initial OH**
 - A rapid, transient drop in systolic pressure of 40 mm Hg and/or diastolic pressure of 20 mm Hg within the first 15 sec of standing
- **OH in people with hypertension**
 - A drop in systolic BP of 30 mm Hg
- **Delayed OH**
 - A reduction in orthostatic BP that occurs after 3 min of standing

Concomitant HR Measurement

- HR Measurement helps to differentiate Neurogenic vs. Non-Neurogenic
 - **Neurogenic**
 - The absence of compensatory increase in heart rate despite hypotension
 - Result from central/peripheral nervous system disorder causing autonomic failure
 - **Non-Neurogenic**
 - Hypotension with compensatory increase in HR (approximately 15 bpm) with preserved autonomic function

95

Orthostatic Hypotension Management Strategies:

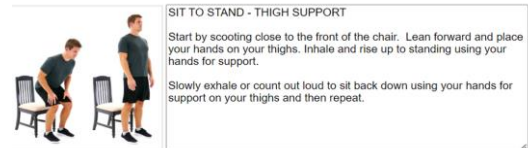
- Hydration = > 64 oz/day (caffeinated drinks do not count)
- Slow movement when getting up
- Movement prior to getting up: ankle pumps, LE marching, bicep curls



96

Orthostatic Hypotension Management Strategies:

- Inhale when changing to a more upright posture
- Exhale when bending down – BEND knees



- Supine/Seated POTS exercise or walking program



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Threshold Exercise/ Exertion Testing

- **Goal:** Asymptomatic exercise for 20 minutes at HR target of 85% of age predicted maximum
= Assumed physiologic resolution of PCD (Leddy et al 2010)
- Recovery improved w/ aerobic exercise@ subthreshold level (80% of maximum HR (Baker et al 2012) and improved HR/BP autonomic function control (Leddy et al 2010)
- **Buffalo Concussion Treadmill Test** (Leddy and Willer, 2013)
 - Evidence to safely and reliably diagnose physiologic dysfunction s/p concussion (Baker et al 2012)
 - Individualize exercise prescription based on HR/BP recorded at threshold of symptom exacerbation
 - Safe to perform on those symptomatic for > 3 weeks
 - If patient can exercise to exhaustion without exacerbation of post-concussive symptoms = symptoms from a secondary diagnosis (cervical injury, vestibular/ocular dysfunction, Migraine, Depression)
 - May need to exert at higher level and add in visual/vestibular activity/dual task with cognition

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98

Obstacles for return to work

- Delay in care, especially with BWC patients with delay in C-9 approval for appropriate therapy or specialist referrals for medical or psychosocial management
- Prolonged symptoms > 30 days
 - Cognitive fatigue
 - Photosensitivity or Visual dysfunction which requires Neuro-optometry consultation and intervention
 - HA with unknown triggers
 - Poor sleep pattern
 - Visual-vestibular integration or visual motion sensitivity deficits
 - Unstable vitals

Impairment based strategies for return to work: Cognitive Fatigue

- Schedule day with adequate mental rest breaks
- Memory Strategies: lists, alarms
- Modifying Environmental Noise and/or Light

Impairment based strategies for return to work: Visual Dysfunction

- Reduce overhead/florescent lighting
- Dim brightness of computer screens
- Blue light filters for computer screens
- If in private office; use of hat or sunglasses
- Increase font size
- Reduce use to only one screen
- Screen to be eye level and at distance without eye strain
- Appropriate rests

Impairment based strategies for return to work: Visual Motion and vestibular sensitivity

- Use of light touch to walls or crossing arms
- Setting environment to limit the amount of multi-directional movement and quick turns
- Reduce computer screen time
- Reduce need to be in face to face meetings

Impairment based strategies for return to work: Cervical Strain

- Ergonomic changes to work space
- Use of head support when possible when doing computer work
- Ice neck during rest breaks
- Intermittent cervical retractions and active stretching

Impairment based strategies for return to work: Headaches

- Rest from known trigger
- If no known trigger, attempt medication or ice pack around neck
- If does not resolve, pursue medical management

Impairment based strategies for return to work: Unstable Vitals

- Stay hydrated
- Monitor HR/BP
- If lightheaded, sit, use hand clasp technique, use compression socks

105

Recommendation Forms

Return to Work

Return to School



Return to Work Recommendations

Patient Name: _____
 Date of Birth: _____
 Today's Date: _____
 Recommendations for modifications for the next: _____ week(s) _____ month(s) _____ Until further notice
 _____ Gradual increase in workload/hours as tolerated
 Days per week Recommendations: 1 2 3 4 5 days ☐ with _____ day(s) rest between
 _____ consecutive days prior to day off
 Hours per day Recommendations: 2 4 6 8
 Break: _____ Permission to take _____ minute break(s) in a quiet area
 _____ Allow to go home if symptoms don't subside
 Visual Stimulus: _____ Allow to wear sunglasses/hat _____ Use only one monitor
 _____ Eliminate or reduce overhead lights _____ Reduce consecutive screen time
 _____ Reduce brightness of screen, allow blue light filter to be used
 _____ Allow patient to be remote for meetings
 Workload/Multi-Tasking: _____ Reduce overall amount of work _____ Allow to wear earplugs as needed
 _____ Reduce productivity standards, allow increased time
 _____ Allow to work in quiet/closed room
 _____ Allow to work remotely from home
 _____ Excuse from after hour work activities
 _____ Decrease/eliminate meetings

Signature _____ Date _____

** This is not intended to be a medical clearance for return to work but are recommendations based on the patient's functional status from a rehab perspective. Recommendations have been made by the appropriate therapy involved in patient care.



SCHOOL RECOMMENDATIONS FOLLOWING CONCUSSION

Patient Name: _____
 Date of Birth: _____
 Date of Evaluation: _____
 Recommendations for _____ week(s)/month duration _____ Until further notice
 Attendance: _____
 _____ No school through date: _____
 _____ Attendance at school _____ days per week
 _____ Partial school days as tolerated by the student
 _____ Full school days as tolerated by the student
 Breaks: _____
 _____ Permission to take short rest breaks in quiet area
 _____ Allow student to go the nurse's office if symptoms increase
 _____ Allow student to go home if symptoms do not subside
 _____ Allow other breaks during school day as necessary
 Visual Stimulus: _____
 _____ Allow student to wear sunglasses/hat in school
 _____ Pre-printed notes for class material or note taker
 _____ Limited computer, TV screen, bright screen use
 _____ Reduce brightness on monitors/screens
 _____ Change classroom seating as necessary
 Physical Exertion: _____
 _____ No physical exertion/athletics/physical education/recess
 _____ Only walking in physical education class until further notice



Audible Stimulus:

_____ Lunch in a quiet place with a friend
 _____ Avoid music or shop classes
 _____ Allow to wear earplugs as needed
 _____ Allow class transitions before the bell

Workload/Multi-Tasking:

_____ Reduce overall amount of make-up work, class work and homework
 _____ Prioritize workload when possible
 _____ Extra time for all assignments, projects and make up work
 _____ Reduce amount of homework given each night
 _____ Excuse from extracurricular activities (sports and non-sports)

Testing:

_____ Excuse from all tests
 _____ Additional time to complete tests
 _____ Take break(s) for testing longer than 30 minutes
 _____ No more than one test per day
 _____ No standardized testing
 _____ Allow for scribe, oral response and oral delivery of questions, if available
 _____ Consider establishment of a 504 plan, IEP or disability services assistance to support learning needs

Signature _____ Date _____

** This is not intended to be a medical clearance for return to school but are recommendations based on the patient's functional status from a rehab perspective.

106

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107

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108

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111

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112

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113

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114

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115

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 SHELBY HOSPITAL + WESTERVILLE MEDICAL CAMPUS + HEALTH AND SURGERY CENTERS
 PRIMARY AND SPECIALTY CARE + URGENT CARE + WELLNESS + HOSPICE
 HOME CARE + 28,000 PHYSICIANS, ASSOCIATES & VOLUNTEERS

116