Traumatic brain injury and concussion

Our brains were evolved to recover from injury. Consider a distant cousin our ours, a *homo sapiens* 10,000 years ago hunting for his family with other members of his tribe. During the hunting party's pursuit of prey, he stumbles down a rocky incline and falls awkwardly onto a large stone, striking the side of his head. He blacks out and is motionless. The other members of his hunting party reach him, and after a brief time he opens his eyes and looks around, speaking confusedly. He is helped to walk back to his shelter, holding his head with an apparent headache. After sleeping nearly around the clock for 3 days, the hunter stays largely within his shelter for three weeks; when he tries to rejoin the hunting party, he has splitting headaches and feels imbalanced. Finally, two months after his injury he feels ready to start hunting, and once again he leads the hunting party on its successful hunts.

The *homo sapiens* brain of 10,000 years ago is not significantly different than our own. Although we have made advancements in knowledge and society, we are born with the same neuronal circuits. Its means of recovering from traumatic injury are the same.

A human from a more primitive society suffers the same type of injury to their brain as we do. As the head hits the ground, the brain's surface bounces within the hardened skull and leads to injury to the neurons, blood vessels and other cells in the brain. The impact may be severe enough to cause nerve cells to misfire and brain circuits to malfunction, causing a momentary loss of consciousness. The fragile connections between neurons may be damaged, and the brain will shift to a recovery state. During this period, which lasts several days to 2-3 months, the individual may feel fatigued, "slow" mentally, and imbalanced. Even though it feels the brain is hardly functioning, there is a dramatic amount of rebuilding of the neuronal circuits. Finally, once the brain has healed itself sufficiently, the individual feels back to normal, and the injury is a distant memory. This process of recovery is the same for the victim of a car collision, NFL athlete, or primitive human.

Compared to other animals, humans are "top heavy:" we walk upright and have relatively heavy heads that are at risk of injury when we inevitably fall. Toddlers and young children fall frequently when they are learning to walk, and adults do so as well when walking on uneven ground, carry items when distracted, or otherwise test the limits of their balance.

In the following few pages we will discuss some details of how our brains are affected by injury and recover from this injury. New research about the diagnosis and treatment of traumatic brain injury will be discussed, and we will offer practical advice about hastening recovery.

What is a traumatic brain injury?

Trauma causing any severity of brain dysfunction would be considered a traumatic brain injury (TBI). TBI is common condition, accounting for approximately 2.5 million emergency visits in the US annually (Gaw, need to pull). A vast majority TBIs are mild in severity, and complete recovery happens for greater than 90% of patients.

The concept is straightforward: when the head is affected by a physical force, the force causes the brain to strike the surfaces of the brain and a force acts as a shockwave through the brain itself. The force acts on individual neurons, and this compressive force causes the neurons to temporarily malfunction. In some cases, loss of consciousness occurs, but typically after mild TBI confusion, disorientation, imbalance and a sense of feeling stunned occurs in the minutes afterward. This force can be from direct trauma of the head onto the ground or another object or indirectly by the head snapping or twisting such as in a whiplash injury.

TBI is classified by paramedics or physicians into mild, moderate and severe categories based on the duration of unconsciousness, hemorrhage into the brain, and presence of sustained weakness or other neurological symptoms.

What are the typical symptoms after traumatic brain injury?

Traumatic brain injury results in a semi-predictable pattern of symptoms.

Headache

Headache is nearly ubiquitous after head injury and often the most debilitating symptom. The typical TBI-related headache may involve the entire head and may be associated with neck stain or focal pain over the posterior or occipital part of the head. In most patients with mild injury the headaches largely resolve after 2-3 months, but up to 30% or more of patients with a mild TBI may have symptoms including headaches 6 months after the injury [add: Hou when a minor head injury, Stulemeijer, van der Werf Early prediction, Norrie J, Heitger M, Leathem J, et al. Mild traumatic brain injury and fatigue: a prospective longitudinal study]. It is thought that trauma to neuron cells causes inflammatory and other changes that are seen in other types of headaches [add Packard and Ham 1997]. The factors that have been shown to worsen the severity of posttraumatic headaches including a previous history of headaches,

Patients with migraine headaches prior to the TBI may find an acute worsening of their headache frequency and severity. Migraines are a specific type of headache, typically affecting only one side of the head at a time with association with nausea and light sensitivity, and migraine are typically episodic, meaning they occur with intensity and then resolve after a number of hours. When patients with TBI and a history of migraine headaches experience a worsening of their migraines, we typically continue treatment with migraine medication, including triptans, anti-inflammatories, and caffeine for acute headaches and migraine preventative agents including magnesium, riboflavin, beta-blockers, topiramate, nortriptyline, and anti-seizure medications.

Post-traumatic headaches are often associated with neck pain that can occurred during the head trauma. Neck muscles, ligaments, and tendons are common sources of pain, and there is a close association between cervical neck pain and chronic headaches. The typical treatments for cervical neck pain, including massage, relaxation exercises, physical therapy, trigger point injections, and muscle relaxant medications are employed in patients with post-traumatic headache associated with neck pain.

Occipital neuralgia refers to nerve-related pain of the occipital nerves that travel from the upper cervical spine, between layers of muscles and soft tissues, and under the scalp to innervate a large part of the head. Any compression of the occipital nerve can result in head pain over the posterior part of the that can be associated with tenderness of the occipital nerve and neck pain. Treatment targets hyperactivity of the occipital nerve by directly blocking the nerve, quieting its activity with neuropathic pain medications, or modulating its activity with pulsed radiofrequency treatments performed under ultrasound.

Post traumatic headache treatments

- Classic post-traumatic headaches
    - Non-steroidal anti-inflammatories: ibuprofen, naproxen and others
    - Acetaminophen
    - Magnesium
    - Memantine
    - Opiate pain medications, brief treatment courses only
- Migraine related post-traumatic headaches
    - Sumatriptan and other triptans
    - Magnesium
    - Riboflavin
    - Butterburr
    - Non-steroidal anti-inflammatories: ibuprofen, naproxen and others
    - Orals steroids: prednisone and others
    - Beta-blockers: propranolol
    - Calcium channel blockers: verapamil
    - Topirimate
    - Nortryptiline
- Cervical neck pain related post-traumatic headaches
    - Massage
    - Relaxation exercises
    - Physical therapy
    - Trigger point injections
    - Muscle relaxant medications, including cyclobenzaprine, magnesium
- Occipital neuralgia related post-traumatic headaches
    - Nerve blocks
    - Neuropathic pain medications: gabapentin, pregabalin
    - Pulsed radiofrequency treatments

Dizziness

Imbalance and dizziness are very common after head trauma, affecting up to 80% of patients [add Sharp, David J, Jenkins, Peter O]. There are multiple causes of posttraumatic dizziness, but fortunately recovery occurs spontaneously in most individuals without specific therapy. In up to 20% of cases, sustained post-taumatic dizziness can occur.

Benign paroxysmal positional vertigo (BPPV) can occur after head trauma. The semicircular canals within the inner ear have a gyroscope-like anatomy and provide balance input when working properly. Head trauma can dislodge crystal-like sensors within these canals, disrupting their function. The symptom that results is a severe sense of room-spinning vertigo that lasts for 10-30 seconds after head turning to one side or another, followed by a sense of imbalance, unease and often nausea that lasts afterward. Severe vertigo that lasts a brief time with specific head movements should be presumed to be related to BPPV. The treatment is a set of head turning exercises called an Epley maneuver designed to reposition the dislodged crystal; these can be performed by an ENT physician, neurologist or physical therapist trained in the technique.

A general sense of sustained imbalance is another typical symptom after head trauma. Balance is a finely tuned function of the brain, involving the feedback of hundreds of muscles throughout the body, based on innumerable sensory inputs giving information on joint position and pressure, and regulated by circuits distributed throughout the brain that function on a millisecond scale. Head trauma can cause all circuits in the brain to function less precisely as damage is repaired, and during this recovery period a sense of imbalance occurs.

The risk of another head trauma during the recovery period of the first trauma is significant, so our sense of imbalance serves to protect us from engaging in activities that may lead to a subsequent fall. Physical therapy targeting balance is often recommended and can hasten recovery. Moreover, anxiety and stress related to imbalance can often delay recovery, and cognitive behavioral therapy focusing on imbalance is an important adjunct.

Migraine headaches can be associated with dizziness, especially at the very onset of the migraine symptoms. This type of migraine, known a vestibular migraine, results typically in severe vertigo that may not be related to head turning as in BPPV. In these cases additional focus on migraine prevention and acute treatment is recommended.

Cognitive impairment

Not surprisingly, cognitive impairment is a common symptom after traumatic brain injury consider the effects on the frontal lobe circuits involving memory, focus, concentration, and executive functions such as planning. A majority of people suffering a TBI may complain of feeling “foggy” or “slow,” and in mild TBI a subtle decline in performance on cognitive testing can be seen after head injury [add Ellemberg D, Leclerc S, Couture S, et al. Prolonged neuropsychological impairments following a first concussion in female university soccer athletes. Clin J Sport Med 2007; 17:369–74]. The areas of concentration, focus, executive functioning, memory and processing speed are typically reported as most affected by TBI. As with other post-traumatic symptoms, full recovery typically occurs within 2-4 months.

For moderate to severe TBI the abnormality can be significant, but in mild TBI testing does not always show a decline in performance as compared to a group of subjects without TBI [add Belanger HG, Spiegel E, Vanderploeg RD. Neuropsychological performance following a history of multiple self-reported concussions: a meta-analysis. J Int Neuropsychol Soc 2010;16:262–7]. For professional, college and other serious amateur athletes participating in contact sport, computerized testing at the start of a sports season is often performed, and this testing is used as a comparison if a patient suffers a concussion while playing. In practice, however, the imprecision of these tests due to significant variability [add Test-Retest Reliability of Computerized Concussion Assessment Programs
Steven P. Broglio] means that most neurologists and sports medicine physicians do not rely solely on computerized cognitive testing when assessing a patient suffering from concussion.

The treatment for TBI-related cognitive dysfunction is largely based upon accommodation of cognitive deficits and slow returning to normal functioning. Returning to cognitive demanding activities including work and school can be frustrating and delay eventual recovery. Cognitive behavioral therapy is a structured approach to increase understanding of deficits, offer accommodations to help with mental slowness, and teach methods to improve cognitive functioning.
Approaches include mindfulness, the use of memory aids, and relaxation activities.

Prescription medications have demonstrated improvement for impaired attention. Stimulants work on the transmission of neurotransmitters between neurons, and improvements in attention and cognitive testing has been shown with treatment of stimulants. Medications typically used in the treatment of Alzheimer's disease, including memantine and donepezil, have been shown to have some positive benefit in patients diagnosed with mild TBI.

Post-traumatic cognitive and memory treatments

- Cognitive behavioral therapy
    - Memory aids
    - Mindfulness
    - Relaxation
- Medications
    - Simulants, including methylphenadine
    - Amantadine
    - Memantine
    - Donepezil
- Improve general brain functioning
    - Address insomnia
    - Treat fatigue
    - Diagnose and treat endocrine dysfunction

Mood effects

The psychiatric and mood effects of traumatic brain injury are often overlooked. Changes in mood are often hard to diagnose, and the frustration resulting from limitation after a traumatic injury mask direct effects on mood. Frontal lobe circuits regulating anxiety, depression, motivation, and frustration are often direct recipients of the concussive forces that result from TBI, and these circuits become dysfunctional as they require the same type of repair that other circuits in the brain do.

The stress involved with an acute injury often results in a picture of post-traumatic stress disorder. The symptoms of intrusive thoughts and memory of the trauma, anxiety regarding eventual recovery, and an increased mind-body stress response require accurate identification and proper treatment including psychotherapy, cognitive behavioral therapy, and pharmacotherapy.

Mood symptoms including depression and anxiety are common after traumatic brain injury. Previous mood symptoms are a risk factor, and it estimated that of individuals suffering a traumatic brain injury, 75% of those with a past history of mood disorder will suffer mood symptoms whereas approximately 45% of those with no such history will suffer a new onset of mood symptoms. The treatment of depression after TBI is essentially the same as compared to those with no history of depression and relies on medications including selective serotonin reuptake inhibitors which can have the benefit of improving memory and cognition in addition to mood symptoms. Anxiety appears to be best treated with a focus on psychotherapy and cognitive behavioral therapy.

Mood impairment frequently overlaps with other symptoms such as cognition and memory loss, sleep, headaches, and fatigue. Consequently, unless psychiatric symptoms and mood are a focus of treatment, it is unlikely that the totality of symptoms will be remediated.

Sleep disturbances

Impaired sleep is very common after TBI. Sleep is much more than the brain shutting down for the night. In order for deep sleep and dream sleep to occur, the brain needs to synchronize its activity, and in fact deep sleep is necessary for normal memory function, concentration, and proper metabolic activity of nerve cells in the brain.

Sleep is surprisingly complex, and the brain functions different at each of the stages of sleep. During wakefulness, EEG shows fairly chaotic activity as different circuits in the brain activate in various patterns. In drowsiness and the first stage of sleep, brain activity quiets. In the deeper stages of sleep, something important happens. The brain's activity synchronizes, and slow waves appear. This slow wave sleep is vital for memory formation and proper brain functioning. It is thought that this synchronistic activity behavior causes the brain circuits responsible for memory to allow for the creation of long-term memories and strengthens the connections (synapses) for sustained memory. Moreover, as discussed below, slow wave sleep allows for waste products generated during normal brain activity to be processed and removed from neurons. There is some variability, but in general we should expect to spend 20% of our night in slow wave sleep.