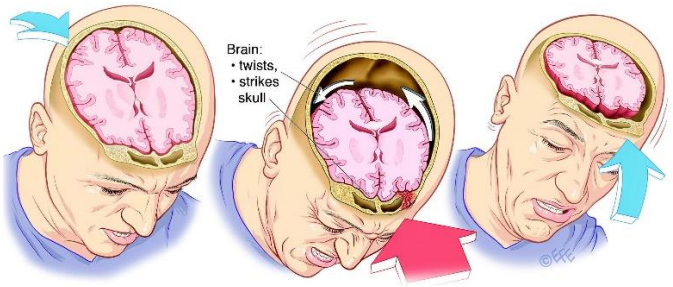
CONCUSSION



What happens to the normal physiology inside the head when you have a concussion? In addition to fluids, the brain has two major layers of tissue: the *cortex*, (the outside layer)**, and the *medulla*,** (the inner layer)**. The cortex is composed mainly of the cells that we refer to commonly as gray matter, while the medulla is composed mostly of exons, the connecting fiber transferring the signal from one neuronal cell to another.**

Football helmets repeatedly colliding, foreheads stunned in a car accident, or head-on-head rugby clashes, a sudden blast near soldiers on foot patrol, or other serious blows to the head, resulting in concussion, all trigger Newton's second law of physics. This is the basic equation of motion: a force acceleration of the body; or, force is equal to mass times acceleration (F = ma). Millions of small blood vessels and long connecting fibers (axons) **are stressed by the friction. Many may rupture. The gray matter-white matter junctions in the frontal and temporal** (side) **lobes are the most vulnerable sites.**

Oxygen supplies fall where this happens as blood flows decline (hypoxia)**. Any tissues starved of oxygen cannot function normally as the volume of available energy plummets as mitochondria fail. However, in 80 to 90% of concussions, blood vessel damage is slight, the tissue can recover, and the initial symptoms, such as fatigue and memory loss, fade within a week or two. Most people recover.**

But when concussion friction severs too many small blood vessels, areas impacted by the diminished oxygen supplies become a bottleneck that prevents or substantially slows healing. Symptoms related to the damage to these biochemical pathways and brain structures may continue for weeks or months in 10 - 20% of the cases. Among those patients, 25 - 33% develop a more permanent brain injury.

Many patients will struggle for years or even the rest of their lives with neuropsychiatric disorders such as depression, anxiety, memory and attention difficulties, and mood and impulse troubles. These setbacks complicate their ability to manage daily functions on their own, such as eating, bathing, and dressing. The diagnosis of *chronic traumatic encephalopathy*, or CTE, closely identified with former football players, is a progressive degenerative syndrome.

What is unfolding is permanent brain injury, an unfortunate cascade of biochemical tragedy. Areas starved for oxygen after a concussion suffer cell death or chronic inflammation. There is a breakdown in energy production from disrupted mitochondria activity and a decline of the brain's biochemical activity. These accumulating malfunctions cause the vitality of synapses and neurons to fade along with molecular communications between neurons.

Lifetime costs for treating one patient with TBI can range from $85,000 to more than $3 million. The financial burden of TBI on individuals, families, national economies, and health systems has been estimated at $56 billion per year.

Brain regions with reduced oxygen supply and diminished metabolism can recover much or all their lost potency. They retain a biological infrastructure on which stem cells can migrate and differentiate into the missing tissue and new blood vessels can grow. The depleted areas have been demonstrated by combining brain metabolic imaging (SPECT) **with anatomical imaging such as standard magnetic resonance imaging** (MRI) **or computerized tomography** (CT)**.**

POST CONCUSSION SYNDROME (PCS)

In most cases, the headaches, dizziness, cognitive decline, mental fatigue, vertigo, mood changes, and other disorienting impacts after a concussion fade away after a week or two. These are classified as *mild traumatic brain injuries*, or mTBI. Life returns to normal for about four of every five people who experience mild-to-moderate traumatic brain injury or jolt to the head. But what about the rest who make up roughly 25% of the people impacted by concussion injuries? For them, the disorienting effects of PCS can extend for months, years, or even become permanent for the rest of their lives.

The deteriorating quality of life for concussion patients who do not recover becomes so significant that they can become extremely frustrated. They become despondent if they are unable to return to satisfying work, retain their normal cognitive functions, or maintain friendships and supporting social networks. Meanwhile, their families can be staggered by the physical, financial, and emotional shockwaves that PCS can trigger.

Traumatic Brain Injury (TBI) **is one of the most common reasons children are taken to emergency rooms, a frequency averaging 150 – 400 of every 100,000 child ER visits. These visits come typically after car accidents, falls from bicycles, blunt force trauma, and sports-related head injuries. Physicians in emergency rooms might consider a serious head injury when they assess a child. But the child usually is released to the care of a primary physician when CT or MRI images indicate no significant noticeable brain damage that needs further attention at that time in the hospital.**

PCS symptoms were evaluated in children eight to fifteen years old between six and sixty months after they were admitted to the emergency department in a hospital because of mTBI. The control group was composed of children of the same age range who also had been admitted to the emergency department but with a different diagnosis, a broken arm near the wrist known as an uncomplicated *distal radius fracture*.

The results demonstrated that approximately one in every four children brought to emergency rooms suffered from PCS, yet none was diagnosed with this brain injury by their caring physicians over time. The more common diagnosis cited one or more of these issues: concentration or learning problems, ADHD, memory problems, chronic migraines or other headaches, depression, sleep disorder, fatigue, and other adaptive disorders. Essentially, no one made the connection between the head injury and post-concussion

symptoms. Based on how most medical systems operate today, they are missing the long-term follow-up of those children who, in the emergency room, did not have any observable motor dysfunction.

Current guidelines for treating concussion injuries only span the first two weeks of symptoms. For children with a misdiagnosed concussion, these medical errors can be tragic. Leaving the condition untreated puts the child at a significant disadvantage and directly impacts their development into adulthood.

Concussion is the number one risk factor for children who develop mental health issues, psychiatric hospitalization, or harm themselves. The impacts from any brain injury during childhood will continue through the rest of that child's life. We must be more alert to any trauma that may have long-term consequences on our children's brains. The loss of any brain functionality will prevent a child from fulfilling their potential in school, university, and social life.

PCS symptoms continue to be misdiagnosed too frequently as emotional or psychological problems. The medical profession has missed the biological problem because their way of looking at the brain is too limited. The magnitude of biological damage cannot be seen with standard brain imaging tools of CT or MRI, so many physicians routinely and erroneously insist to a patient that they do not have a "real" biological brain injury; they "only" have an emotional problem. That increases a patient's frustration even more.

Traumatic brain injury has become a major public health concern globally for both civilian and military populations, with at least ten million new head injuries occurring annually. It is a leading cause of death and disability in the United States, with an estimated average of 1.4 million cases per year; of these, 50,000 will not survive a severe TBI, 235,000 will be hospitalized, and another and the remaining 1.1 million will be treated and discharged from emergency departments. Less severe but still dangerous, concussions are more prevalent, typically stemming from motor vehicle accidents (50%)**, falls** (38%)**, sports injuries, and violence, including attempted suicide.**

There are no accurate statistics on mild TBI because most people with this concussion injury don't go to a hospital, and 25% of those who do are never reevaluated beyond the time of the injury. About 2% of the population are living with long-term disabilities resulting from TBI.

SPORTS-RELATED INJURIES

Concussions suffered during sports and recreation activities each year amount to between 1.7 and 3 million cases; football drills and competitions, beginning in elementary school and up through professional teams, contribute 300,000 of those. There have been sobering declines in the personal lives of former professional football players in the United States who struggled with escalating mood disorders, paranoia, memory loss, and an array of erratic behaviors, such as explosive rages.

Brain analyses after some of their deaths showed evidence of *chronic traumatic encephalopathy* (CTE)**, a progressive degenerative disease linked to repetitive blows to the head over many years that in some cases may have led to former players' suicides.**

MILITARY-RELATED BRAIN INJURIES

Soldiers also are highly vulnerable to concussions and complex neurological impacts from blast injuries. Blast waves release light, sound, heat, and electromagnetic energy that, combined with effects of the ultrasound pressure wave, can damage the central nervous system. Abrupt pressure changes inflicted on the brain can cause bubbles to form in extracellular fluids of the brain. These bubbles can damage the brain's surface and produce a shock wave through brain matter, as well as impair capillaries, lodge in blood vessels, and reduce blood flows. Each of the latter three can starve tissue of oxygen.

The Pentagon puts the number of military service members diagnosed with TBI between 2000 and 2019 at more than 400,000. US military officials regard TBI as the signature injury of the Afghanistan and Iraq military conflicts; with 28% of soldiers evacuated diagnosed. Risks in combat zones exposed may—especially on foot patrols—to stunning explosions, often from remote controlled devices that propel shock waves of highly compressed air. Three-fourths of soldiers who sustained any type of TBI were wearing helmets when they suffered these injuries.

Most diagnosis came directly from active soldiers or veterans who sought medical help for hearing problems or headaches. Psychological setbacks often followed, typically from depression and *post-traumatic stress disorder* (PTSD)**, but episodes of anxiety and troubles with sleep, focus, and clear thinking are also common.**

HBOT AND POST-CONCUSSION SYNDROME

Diagnosing PCS is not easy. For one thing, standard brain scans from CT and MRI will not show any significant damage from *mild traumatic brain injury* (mTBI)**. Moreover, scientifically measuring whether someone's cognitive ability declined or whether any mood patterns, such as depression or anxiety, existed before the concussion or became more pronounced due to damage in the frontal lobe is rarely possible.**

Patients can receive metabolic imaging by a specific SPECT scan (advanced technology that was well established by 2008) **of their brains, before treatment begins. Methods, such as perfusion MRI, monitoring radioactive tracers in *positron emission tomography*** (PET)**, or SPECT scans enable us to see brain regions with metabolic dysfunctions in an objective manner. Both measure brain activity by identifying changes associated with blood flows to tissues.**

You can't rely on someone's perception that a concussion was causing them mental or physical problems. You need to see the metabolic dysfunction—the brain tissue wounds—with advanced SPECT images that can detect altered or blocked blood flows. The goal is to objectively evaluate whether there is damage in the brain. Some patients cry tears of joy when shown the images confirming concussion brain damage. They were profoundly excited, relieved to know they had not been imagining the post-concussion mental and physical struggles that were pulling them down.

The first clinical study on the use of HBOT for healing concussion damage was initiated in 2010. The results more than fifty participants with PCS showed significant improvement in their speed in processing information as well as their attention (focus)**, memory, and executive functions.**

When a patient tells you they are fully recovered, this is the greatest reward you can experience as a physician. Most participants in the PCS clinical study fully recovered. There was no significant improvement in the control group during eh control period. After these participants completed their final evaluation for the two-month study, they were all allowed to receive the same full HBOT protocol they had give to the treatment group. They also improved.

HBOT induces significant improvement in memory, and cognitive functions. Specific PCS symptoms that improve include emotional scores, behavioral issues such as hyperactivity, and abilities to plan and organize activities. MRIs show correlating positive changes in the area of the cortex associated with PCS symptoms, leading to significant improvement in measurements for memory, verbal fluency, and executive function. In contrast to the treatment group, there is no improvement in the baseline scores of participants in the placebo/sham group.