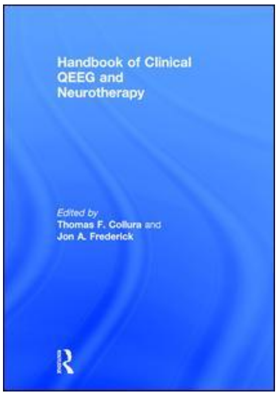

Handbook of Clinical QEEG and Neurotherapy

Thomas F. Collura, Jon A. Frederick

Concussionology

Publication details
https://www.routledgehandbooks.com/doi/10.4324/9781315754093.ch11
Harry Kerasidis
Published online on: 17 Nov 2016

11

CONCUSSIONOLOGY

Sport Concussion Management

Harry Kerasidis

Abstract

There is a growing awareness of the repercussions of a concussion and, increasingly, clinicians are called on to treat post-concussion syndromes. This review covers the elemental basics of concussions in terms that will not only inform clinicians but patients themselves. Standard neurological concussion treatment is described. Advanced treatment techniques of neurofeedback and neuromodulation are presented. Case studies illustrate treatment protocols using QEEG-driven selection of targets for training.

The brain is beautiful, the new frontier of science. However, the brain is also vulnerable. Its fragile, gel-like consistency floats unattached inside the skull. When force is applied, as it does many times in sports collisions, military injuries, work accidents and motor vehicle accidents, the brain sloshes from side to side, end to end, almost like scrambling the yolk of an egg as it floats inside, without breaking its shell.

The consequences from concussions and undiagnosed brain injuries can be seen immediately or take several hours or even days for symptoms to materialize. However, their effects can be life altering. It is a mystery that medical science is unraveling.

For example, the *Wall Street Journal* reported on the front page in 2008 that undiagnosed brain injuries are a major cause of:

- Homelessness
- Psychiatric illness
- Depression and anxiety
- Alcoholism and drug abuse
- Suicide
- Learning problems

To understand concussions and mild traumatic brain injury, first we need a better understanding of the brain itself. It is a wonderfully complex organ, and "command central," literally responsible for regulating or executing every move we make, every word we say, every emotion we feel and every thought we think.

Brain health is so critical to proper life functioning that maybe protective helmets should include a label: "WARNING: Contents Are Fragile."

Brain Matters

The consistency of the brain is between slightly set gelatin and peanut butter, almost like impressionable memory-foam pillows.

Despite being encased within the stone-like skull, the brain can be easily affected from outside trauma. Its soft texture is impressionable, like a banana. Therefore, when the brain bounces inside the skull, it does not immediately spring back into shape. The brain is in continual use, so when it experiences trauma—like a hard fall or direct hit to the head—normal functioning can be interrupted momentarily or for longer periods of time.

Since we cannot see the brain, unless we use a form of scanning, we must assess for potential damage from a variety of visible or felt symptoms, and measures of brain performance.

The brain directs our body to digest food we eat, signals the heart when and how to react, it administers healing when it perceives trouble, and so many other functions. When the brain experiences a form of trauma, whether physical, mental or emotional, it has the power to begin a self-healing process.

However, it is important to note that our conscious behaviors can influence the healing process as well. For example, the kind of food we eat either helps or hurts our brain. Getting enough sleep and drinking enough water influence the brain. In addition, toxic chemicals from tobacco smoke, drug use, alcohol and even fumes from paint or hair and nail salons can drastically reduce the brain's effectiveness.

Brain Basics

The brain is not a uniform mass of tissue. It is made of several sections. The brain is also composed of billions of specialized cells, called neurons and glia.

- The brain floats within fluid inside the skull that has ridges and shelf-like areas, which is why it is vulnerable to jarring hits or whiplash-type action.
- The brain requires significant blood flow and oxygen to operate. The brain makes up about 2 percent of our body weight, but consumes 20 percent of the oxygen we breathe and 20 percent of the energy we consume.
- This enormous consumption of oxygen and energy fuels billions of chemical reactions in the brain every second. This is perhaps one of the most motivating reasons to provide the right kind of fuel, with a healthy diet and regular exercise.

Brain Anatomy

Regions

The brain is organized into three main sections: the cerebrum, cerebellum and the brainstem. Trauma received in any of these areas tends to cause problems associated with that area's functions. Any sudden movement with force can result in the brain sliding back and forth which can cause temporary or permanent cognitive damage.

The most vulnerable areas of the brain are the frontal and temporal sides (lobes) due to their anatomy and proximity to the skull.

- *Frontal*: Responsible for executive functioning, forethought, planning, organizing, complex thinking, focus and concentration, and emotional self-regulation.
- *Temporal*: Responsible for auditory processing, short-term memory and mood regulation.

Below is a brief overview of some of the key areas of the brain, and associated behaviors which can be affected by concussions and more severe brain trauma.

1. **Cerebrum**—The "forebrain" is the largest area of the brain, and is divided into left and right sections called hemispheres.

   Prefrontal Cortex (PFC)—Damage to the PFC can result in poor decision-making, impulsivity, short attention span, lack of goal setting and procrastination.

   Anterior Cingulate Gyrus (ACG)—Running lengthwise under the PFC, the ACG regulates our ability to shift attention when needed, adapt to change and be flexible in thought and reasoning. When this area of the brain is not working properly, people can get stuck on negative thoughts or actions, become overly worrisome, hold grudges and be oppositional or argumentative.

   Temporal Lobes—The temporal lobes are involved in auditory processing, language, short-term memory, mood and temper stability. They also help interpret and name what things are. These lobes often experience trauma from jarring hits from contact and collision sports that can lead to problems with memory, mood and temper.

   Parietal Lobes—The parietal lobes are involved with sensory processing, spatial relations and direction sense. Typically, Alzheimer's disease will impact this area, giving people with this condition a hard time with finding their way and getting lost. Other problems with parietal lobes can lead to inaccurate interpretations of body perception.

   Occipital Lobes—The occipital lobes are involved with vision and visual processing. Information taken through the eyes are sorted out in the occipital lobes and dispersed to the various regions of the brain for action.

   Limbic System (LS)—Arching deep inside the brain, from the frontal lobes through the parietal lobes to the temporal lobes, the LS helps set emotional tone, either positive and hopeful or negative and desperate. Problems with the LS have been linked to low motivation, poor self-esteem and feelings of depression, helplessness and hopelessness.

2. **Cerebellum**—The cerebellum is the "coordinator," involved with voluntary physical (motor) movements, posture, balance, motoric coordination, processing speed and facilitating the PFC's role of helping with judgment and impulse control. Trouble with the cerebellum leads to motoric coordination problems and ability to learn.
3. **Brainstem**—The portion of the brain that is continuous with the spinal cord at the base of the brain. The brainstem relays signals from the brain throughout the body via this section, controlling and regulating vital body functions including respiration, heart rate and blood pressure.

If there is trauma experienced in any of these processes, the brain's ability to process the behavior can be affected.

Brain Talk

Features of brain physiology make the brain an electro-chemical organ. The electrical and chemical physiology of the brain are inseparable. Yet, medical science has largely focused on the chemical side of the brain, attempting to modulate function, or restore physiologic balance using pharmacological agents. Only recently has medical science turned to technology that allows clinicians to modulate the electrical physiology of the brain such as neurofeedback, transcranial direct current stimulation and transcranial magnetic stimulation. In my clinical practice, I have found that a balanced approach using neuromodulatory technology, nutritional support, pharmacologic interventions and physical/occupational therapy results in optimal outcomes in helping those with mild traumatic head injury return to normal daily activity.

Brain Gain

The brain develops rapidly throughout early childhood. Neurons are making billions of connections during the first few years of a human's life. The brain continues developing until the age of 25 years for most. Even the adult brain generates new neurons within a region important for learning and memory. The brain's ability to change and reorganize in response to some input is known as *plasticity*.

Learning is a form of plasticity, since it leads to structural changes in the brain. While brain plasticity can be gained, it can also be drained. Plasticity is highly dependent on the health of the brain, which is largely dependent on lifestyle factors, brain injuries and other brain-related training.

When the brain is traumatized, there can be lapses within the typical brain function, which is revealed through symptoms. Moreover, these lapses can lead to future cognitive and emotional impairment.

Concussion Definition

So what is a concussion? Does every hit to the head cause one? How severe is a concussion? Does a loss of consciousness qualify as a concussion?

Concussion is a brain injury. Think of shaking an egg yolk inside its shell or a bruised banana.

One may think of a concussion like a brain sprain, because it is usually disabling, but typically can recover with a lot of rest. Like an ankle sprain, a concussion has temporary consequences, and if not healed properly, can result in residual, and degenerative, difficulties. You may be able to continue playing on an ankle sprain, and brain sprain, but if you do, the risk of greater injury increases. As with ankle sprains, the reported severity of a concussion is often minimized and that is something you do not want to do.

Here are other medical association definitions:

1) "Concussion is recognized as a clinical syndrome of biomechanically induced alteration of brain function, typically affecting memory and orientation, which may involve loss of consciousness (LOC)" (Giza et al., 2013, p. 8);
2) "The formal medical definition of concussion is a clinical syndrome characterized by immediate and transient alteration in brain function, including alteration of mental status and level of consciousness, resulting from mechanical force or trauma. People with concussions often cannot remember what happened immediately before or after the injury and may act confused" (American Association of Neurological Surgeons, 2011, p. 1);
3) Here is a consensus statement from an international conference report:

   Definition of Concussion

   Panel discussion regarding the definition of concussion and its separation from mild traumatic brain injury (mTBI) was held. There was acknowledgement by the Concussion in Sport Group (CISG) that although the terms mTBI and concussion are often used interchangeably in the sporting context and particularly in the US literature, others use the term to refer to different injury constructs. Concussion is the historical term representing *low-velocity injuries that cause brain "shaking" resulting in clinical symptoms and that are not necessarily related to a pathological injury*. Concussion is a subset of TBI and will be the term used in this document. It was also noted that the term *commotio cerebri* is often used in European and other countries. Minor revisions were made to the definition of concussion, which is defined as follows:

   - Concussion is a brain injury and is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces. Several common features that incorporate clinical, pathologic and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

- Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an "impulsive" force transmitted to the head.
- Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.
- Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.
- Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in some cases symptoms may be prolonged.

(McCrory et al., 2013, paragraphs 6–7)

Severity

The severity of brain injuries range on a spectrum from mild to moderate to severe. Concussion is widely considered a mild traumatic brain injury. Concussion is an injury that can last hours, days, weeks or even months, with the persistent symptom complex referred to as Post-Concussion Syndrome or mild traumatic brain injury (mTBI).

Concussion Signs and Symptoms

The most important factor about signs and symptoms to know is that they may not materialize until several minutes, hours or days after the injury occurs. This makes concussion detection a tricky business, because the victim may not make the association of delayed symptoms such as headache with the collision injury.

Below are explanations of common signs and symptoms. These symptoms result in temporary lapses according to the areas of the brain that have been affected.

A variety of signs accompany concussion including somatic (such as headache and vertigo), cognitive (such as difficulty with memory or concentration), emotional (such as worry, mood or anger problems), and physical signs (such as loss of consciousness, numbness, weakness and loss of balance).

It is also important to note that any these symptoms often result in combination with the others.

- *Loss of Consciousness*—This is the most obvious, and scariest, sign of a concussion. However, only 10 percent of concussions result in loss of consciousness, according to a 2010 Pediatrics review article (Halstead, Walter & The Council on Sports Medicine and Fitness, 2010). When a player gets "knocked out" temporarily, the brain continues serving its involuntary functions, but its conscious and voluntary functions discontinue. During this period of time, it is important not to move the individual, and allow the brain to "re-boot" for a few seconds.
- *Confusion*—The most common symptom is temporary confusion, often associated with a "dazed" look or vacant stare. A confused, concussed individual probably will not talk much, because the brain is trying to restore order and understand the circumstances. If the individual does talk, the words may be jumbled, rapid or generally nonsensical and irrelevant.
- *Amnesia*—Amnesia is temporary memory loss that can be divided into two types:
  - Retrograde: Forgetting things that happened before the incident.
  - Anterograde: Inability to remember facts after the concussion.

- *Disorientation*—Related to spatial relations, a concussion can affect the individual's ability to know where they are, what day it is and what they were doing at the time of the injury. The athlete may get up and go to the wrong huddle or sideline.
- *Delayed Verbal/Motor Response*—Slow, slurred or incoherent speech as well as inability to move or walk normally can be associated with concussion.
- *Inability to Focus*—A concussion may be evident if the individual has trouble paying attention, or focusing on the conversation or game situation.
- *Headache*—When due to concussion, headaches are very similar to migraines and may be accompanied by nausea, vomiting and sensory sensitivity.
- *Disequilibrium*—A problem with balance, and feelings of dizziness are common signs.
- *Visual Disturbances*—The vision may become blurred, doubled or overly sensitive to light.
- *Nausea/Vomiting*—May occur in the absence of headache.
- *Emotional Lability* (mood swings)—When hits occur to the sides of the head, or temporal lobes, you may notice anger outbursts, inappropriate laughing, extreme sadness or overt stubbornness not typical of the individual.
- *Sleep Disruption*—Excessive drowsiness or inability to sleep are usually delayed symptoms of a concussion presumably due to disruption of the sleep pathways rising up through the brainstem, and imbalance of the neurotransmitters.

The majority of our understanding of the complex changes in brain physiology due to traumatic injury comes from studies of mild traumatic brain injury occurring in military and athletic settings.

The Physics of Concussion Injury

When outside force is applied to the supple and most important organ in the body, problems can occur. Memory can be forgotten. Emotions can be triggered. Impulsive decisions can be unleashed. Headaches can invade. Motivation can fade. Disabilities may develop. Some injuries have the capacity to alter a person's sense of self, while others affect abilities, such as speech or vision, but do not affect a person's sense of who they are.

The resulting "brain drain" is definitely another force to be reckoned with. However, it is important to emphasize that I do not intend my term—brain drain—to be derogatory. Neither do I want to confuse drain with brain sprain, a phrase I use to describe concussion and mild traumatic brain trauma, which can lead to permanent neurological impairment, headache disorders and Chronic Traumatic Encephalopathy (CTE) that have much more dire consequences than a musculoskeletal sprain. Instead, "drain" refers to reactions resulting in the brain when concussion occurs, due to increased struggle with supplying the metabolic demand for healing.

Mechanisms of Concussion Injury

"Mechanisms" refers to the ways the brain may be injured. You might think of a brain injury, or concussion, like a bruise to a banana. The exterior peel can only sustain so much pressure before the inside meat of the banana is bruised. The same goes for the brain and skull. Although the skull can sustain more forceful blows, the brain inside can become bruised, limiting the oxygen and blood flow in that particular area resulting in various symptoms. Unlike the banana, however, the brain can heal itself with proper health and lifestyle changes, or with certain medication interventions.

However, the skull does not have to suffer a blow for the brain to be injured. A concussion may occur in any or all of the following scenarios:

- Head to head contact
- Head to object contact

- Head to ground contact
- Head to body part contact
- Non-head contact due to sudden change in direction, i.e. whiplash.

Types of Contact

There are different types of contact that affect the brain. The following terms explain the differences, which also give insight to what symptoms may result.

- *Focal Impact*—The brain injury is located where the head was hit, point of contact.
- *Linear* (or Translational)—Brain injury that occurs as the brain moves within the skull. The brain sits inside the skull buoyed by fluid, and can slide back and forth. With enough force, like with a whiplash, or focal impact, the brain can be injured on both the "coup" side and the "contra-coup" side:
- *Coup*—The location where impact is received.
- *Contra-coup*—The opposite side where the brain is damaged resulting from a recoil or counter movement. The contra-coup injury occurs when the brain "bounces back" from the focal location, injuring the opposite side. An example would be a hard fall that lands a person on their back. The back of the head slams the ground (coup, focal), and the brain's momentum immediately bounces forward to collide with the front area of the skull, affecting the prefrontal cortex.
- *Angular* (or Rotational)—Concussion resulting from a sudden head twist, causes shearing injury to the deeper tissues of the brain and to the brainstem.

** Important Note: The rotational injury is the worst type of concussion injury, associated with the most serious neurological injuries.*

In my experience, rarely do concussions occur from only one mechanism of injury. Typically, they are realized in combination. The most common type of contact that results in a concussion is when all three of these mechanisms are involved, focal, linear and rotational.

Pathophysiology

Pathophysiology explains the abnormal effects of a concussion or brain injury to the physiology of the brain. This is my particular area of specialty as a cognitive neurologist. Getting to the root-cause of concussions helps to understand the treatment options and ways to enhance the overall health of the brain. We look at traumatic injuries from macroscopic, microscopic and molecular views:

- *Macroscopic*—This refers to the tissue changes that occur with brain injury such as a concussion from a "naked eye" perspective:
  - Direct Trauma—Tissue changes resulting from direct trauma, which leads to traumatic brain injury. This is analogous to the fracture of a bone, the crush of a muscle or the laceration of skin.
  - Cerebral Blood Flow—Changes to the volume of blood flow to brain tissue resulting from the trauma. This may lead to secondary ischemic injury or stroke, which are problems resulting from insufficient blood supply in more severe injuries.
  - Hemorrhage (or Bleeding)—Hemorrhage can occur in various regions. There is a leathery cover of the brain and spinal cord called the "dura." Trauma can cause bleeding outside the dura called an "epidural hematoma." Torn arteries usually cause these, and so under high pressure, this kind of hemorrhage can lead to rapid and severe neurological deterioration and even death. Bleeding can occur under the dura, known as a "sub-dural hematoma."

These are usually due to tears of the veins, under much less pressure, with a slower deterioration, but could still lead to severe neurological impairment or even death. When bleeding occurs in the space immediately outside the surface of the brain, it is called a "subarachnoid hemorrhage." When caused by trauma, a subarachnoid hemorrhage is not usually fatal, but can be associated with neurological impairment, severe headache and, rarely, a delayed spasm of the blood vessels that may lead to stroke. Finally, bleeding can occur within the tissue of the brain itself. This usually is like a bruise in the brain tissue associated with the direct tissue injury, or can be under pressure due to a torn blood vessel, where the pressure itself can cause further injury, and become life threatening.

- *Microscopic*—The microscopic view is much more important because many of the changes due to brain injury happen on a cellular level.

  When the brain sustains an injury, the membranes of the brain cells stretch, and lose their ability to regulate the environment of the cell. The membranes get "leaky," preventing the brain cells from working properly, leading to dysfunction which can affect behavior, concentration, memory and other cognitive function.

  Additionally, brain trauma increases the metabolic demand—or energy—necessary to repair the brain and regain the equilibrium inside the cell or neuron.

- *Molecular*—Brain trauma causes changes in the neurons, preventing the brain from working normally, including:
  1. *Inability to regulate electrolytes*, which prevents the brain cells from operating properly. In the brain's natural or healthy state, the brain cell maintains the balance of salts and electrolytes inside and outside the cell. It takes energy to maintain that balance. When the brain is damaged, the membrane of the cell leaks out potassium while sodium leaks in. Therefore, the cell has to expend more energy to maintain this balance than before. The effect is that the brain cell does not work properly in that particular region. For example, if the brain damage and leaky electrolyte balance occur in the area responsible for memory, then the result is short- and possibly long-term memory loss.
  2. *Releasing of toxic excitatory neurotransmitters* such as "glutamate" which are toxic to the cell. Although glutamate naturally occurs for proper brain function, when there is too much released as a result of brain trauma, then it results in dysfunction and further injury to the brain cells.
  3. *The concussion energy crisis:* These injured neurons have a harder time getting enough glucose into the cells as they struggle to repair themselves and regain their equilibrium. The entry of glucose into the cell depends on the proper functioning of a protein embedded in the cell membrane called the glucose transporter protein. After the stretch injury to the neuronal cell membranes, the glucose transporter protein does not function properly. The markedly increased demand for energy coupled with the reduction of available fuel leads to an energy crisis in the affected brain cells associated with brain dysfunction. Furthermore, with reduced blood flow, energy metabolism shifts from aerobic (using oxygen) to anaerobic metabolism resulting in a release of lactic acid. Lactic acid also can build up because of the trauma, which is further toxic to the brain cells (local lactic acidosis).

* *Important Note: This is the main reason the brain needs rest immediately following a suspected concussion. You do not want to add more metabolic demand to the brain during recovery.*

Brain Mapping

Here is an overview of the various types of "brain scans" and what you can expect, should red flags of brain injury present after head trauma. I believe the best technique to measure the brain's function is a QEEG.

- *CT*—Computed Tomography is typically what the Emergency Room doctor will order for someone suspected of having a head injury. A CT scan is a static imaging method, featuring a computer-assisted method of assembling a "cross-section" X-Ray image of the brain. While the CT scan will reveal hemorrhaging, skull fractures and other structural abnormalities, it will not be able to distinguish the subtle changes resulting from a concussion.
- *MRI*—Magnetic resonance imaging reveals the anatomy of the brain in greater detail than the CT and depicts a black-and-white virtual "section" of the brain. Using specialized techniques, an MRI may detect the shearing force injury and micro hemorrhages associated with concussion injury.
- *fMRI*—Functional magnetic resonance imaging is similar to that of MRI imaging. However, fMRI imaging takes advantage of a special property of tissue chemistry associated with metabolic activity. fMRI images provide scientists with both functional and anatomical information about brain tissue.
- *PET*—Positron emission tomography allows scientists to view metabolic brain activity. PET works by measuring the distribution and movement of radioactively labeled molecules in the tissues of living subjects. The technique can be used to investigate changes in brain activity while the subject performs assigned tasks. Computers reconstruct PET scan data to produce two-dimensional or three-dimensional images. While MRI scans are used for research and in clinical settings for patient diagnosis, PET scans are used exclusively for research.
- *SPECT*—Similar to PET, single-photon emission computed tomography (SPECT) provides functional brain imaging, showing a three-dimensional view of the brain and measuring the blood flow and activity in the brain. It is cheaper than PET scans and does not require a cyclotron nearby to produce the necessary radioactive dyes.
- *QEEG*—In my practice, I prefer using quantitative electroencephalography (QEEG) to study brain physiology. This inexpensive technology measures electrical patterns at the surface of the scalp that reflect cortical electrical activity in the brain. This real-time measurement records various electrical rhythms of the brain that we can measure accurately, and map with statistical comparisons to normative populations, and therefore localize areas of the brain that may be traumatized. Advanced computer technology now allows for two-dimensional and three-dimensional mapping of the electrical activity of the brain, along with statistical comparison of an individual's brain activity to a normative database. Furthermore, newer database technology allows for discriminant analysis for comparison of an individual's EEG to a database consisting of individuals having suffered mild traumatic brain injury to determine if there is a statistical match to the EEGs of brain-injured individuals.
- *Cognitive Event Related Potentials*—In the same way that PET, SPECT and fMRI scans can be done while the subject is performing cognitive, thinking and memory tasks, the electrical responses of the brain can also be measured and mapped to identify regions of dysfunction related to a specific cognitive task. Although this mapping lacks the spatial resolution that imaging studies such as MRI have, EEG analysis makes up for this with very high temporal resolution, with ability to record events measured in milliseconds, rather than the several minutes required to do other imaging scans.

However, it is important to note that none of these imaging techniques serves as the ultimate, or final answer to detecting a concussion. They may, however, serve critical roles in the assessment process to gather information for a specialist to make a diagnosis and a prognosis of recovery. It is important to recognize that, currently, there is no test that is diagnostic of concussion/mTBI.

On the horizon, the medical world is beginning to see the concept of biomarkers to help with detecting concussions. Using blood and saliva tests, we are continuing to learn that changes occurring in the brain may be apparent in these fluids.

According to a study by Pastun Shahim et al. (2014), blood levels of total-tau—a protein signaling axonal damage in the brain—could be used as a biomarker to gauge severity of concussions in athletes and to assess when it is safe to return to play. The study showed that the plasma levels of T-tau increased in ice hockey players with sports-related concussions. The highest concentrations of T-tau were measured immediately after the injury, and the levels declined during the first 12 hours, followed by a second peak between 12 and 36 hours. Importantly, T-tau concentrations at one hour after concussion predicted the number of days it took for the concussion symptoms to resolve and the players to return to play safely.

Researchers at George Mason University are comparing preseason samples of saliva to the samples from kids who suffered head injuries. They think the change in saliva proteins after a concussion may become a non-invasive way to identify the presence of a concussion (Bradley, 2013)

As can be seen, diagnosing a concussion and traumatic brain injuries is not a cut-and-dry process.

Repercussion Factors

Unfortunately, when the brain is injured, the injury causes malfunction. While concussions are a milder form of brain injury, a number of factors influence how well the brain heals and what functions may be altered. As the brain grapples to return to normalcy, it often builds alternate paths for the neural signaling to occur. This can result in a change in performance that can appear to be a change in someone's personality.

Some factors that influence the lasting impression concussions may have include:

- *Heredity*—Genetic history of neurological disorders can be passed down. Although these genetic profiles do not automatically guarantee a future of disorder, they can have an influence. Heredity can also influence the vulnerability or susceptibility to develop neurological conditions.
- *Gender*—A number of studies have identified that women are more vulnerable to concussion injury than men (Fakhran, Yaeger, Collins & Alhilali, 2014; Guerriero, Proctor, Mannix & Meehan, 2012; Hootman, Dick & Agel, 2007; Kerasidis, 2014; Marar, McIlvain, Fields & Comstock, 2012). In any sport (such as soccer) where women compete as well as men with the same rules, the incidence of concussion injury is greater in women (Lincoln et al., 2011). A variety of factors has been postulated as contributors to this phenomenon. Women have smaller neck sizes, making the head more likely to "whiplash"; about 20 percent of women suffer from migraines; and women are more likely to express concerns about their health than men.
- *Pre-Natal Health*—The health of your brain directly relates to health of your mother during pregnancy, particularly during the first trimester. During this phase, the human brain development is largely based on the level of nutrition, exercise and psychological condition of the mother. Alcohol, smoking tobacco and drug use during pregnancy can inhibit brain development, which can have negative effects on the whole neurological system in the future.
- *History of migraines*—Individuals with a history of migraines are more vulnerable to post-concussion symptoms than those without.
- *Previous Brain Injury*—One concussion offers enough risk for the future. However, when they add up, then the brain is forced to work around the problem area. Any previous brain injury, whether it was diagnosed, perceptible or recognized, can lead to future problems.
- *Lifestyle*—The future health of your brain is made of the past—heredity, pre-natal health and previous brain injury—but also the present. The lifestyle, or in other words, how well someone takes care of their health, can affect future risk of impairment.
- *Nutritious Foods*—Diets void of healthy carbohydrates, protein and water can leave the brain gasping for nutrition critical for proper cellular development and operation.

- *Exercise*—With sports, we often assume athletes lead a life with regular exercise. However, it is not always the case, particularly after the playing years. Low levels of exercise reduce blood flow to the brain, creating vulnerability to injury.
- *Sleep*—Rejuvenating restful, deep sleep is required for the brain to work optimally. Low levels of sleep force the brain to work harder than necessary to perform normal functions. When brain injury occurs, the brain may be at a deficit already due to lack of sleep which can extend the healing period, and risk of impairment.
- *Alcohol*—Drinking alcohol alters the brain chemistry, affects memory and leaves a toxic—or poisonous—presence that reduces overall brain function. Alcohol is a neurotoxin. However, perhaps most concerning is that the brain cannot heal as well from injury when there are residual effects of too much alcohol.
- *Drug Use*—Illegal drug use is not only highly addictive, and leads to bad decisions, but drugs also leave toxic elements in the brain that "weaken" the brain's ability to operate properly. The more drugs are present, the easier a brain can be damaged from blunt trauma such as a concussion.
- *Smoking Tobacco*—Not only does nicotine affect memory negatively, but also tobacco is loaded with many additives and carcinogens, which are also toxic to the brain. Like alcohol and drug use, a toxic brain is more susceptible to the effects of concussion injury.
- *Environment*—The air we breathe, the water we drink and other toxins found in foods can affect our brain health. For example, fumes from paint, nail and hair salons, if absorbed frequently, can reduce your brain's ability to heal quickly.

Cognitive and Emotional Impairments

Other than dying or paralysis from complications suffered from brain trauma, the most serious concussion repercussion is a decrease in overall quality of life due to headaches and a variety of cognitive and emotional impairments that may develop as the post-concussion syndrome. Memory loss, attention span, and poor decision-making are warning signs of brain-related trouble. An estimated 50 million Americans suffer from disorders of the brain or nervous system. Some brain disorders are influenced by genetics, some are environmental, others from spinal cord or brain injury; and some result from a combination of any or all of these factors.

Traumatic brain injury (TBI) refers to damage resulting from trauma to the brain. TBI, like spinal cord injuries, may result in impaired physical function. Injuries to the brain can affect cognitive abilities or disturb behavioral and emotional functioning. In addition, brain trauma has the potential to alter personality, and the sense of self.

TBI by Region

Trauma to different regions of the brain results in different types of disabilities. Some injuries have the capacity to alter a person's sense of self, while others affect abilities, such as speech or vision, but do not affect a person's sense of who they are. Functional imaging has greatly aided the ability to locate the region of the brain responsible for behavior.

In my practice, I avoid using "labels" for various conditions, preferring to understand the physiological issue causing the symptoms. Nevertheless, I have grouped a number of cognitive and emotional impairments that may occur should a concussion, or repeated sub-concussive hits, lead to degenerative brain or neurological damage (in alphabetical order):

Alzheimer's Disease—Researchers believe Alzheimer's and other forms of dementia actually start decades before people experience their first symptoms. This may, in part, have to do with related brain trauma. Alzheimer's is a progressive, degenerative brain disease that leads to loss of cognitive function and short- and long-term memory, behavioral changes, personality changes, and impaired judgment. Typically affecting the temporal and parietal lobes, the brains of Alzheimer's patients also contain tangled masses of abnormal protein in the cerebrum.

A recent study (Mielke et al., 2014) reported evidence of a link between concussions and Alzheimer's disease-related neuropathology. The conclusion stated that self-reported head trauma by individuals with cognitive impairment was associated with greater amyloid deposition. Amyloid is associated with the brain plaques and tangles seen in Alzheimer's disease. Additionally, risk factors for chronic neurobehavioral impairment include repeated concussion exposure and APOE e4 genotype (Giza et al., 2013).

Anxiety—Anxiety is an emotional response from over-anticipation of a real or perceived future threat, according to the *Diagnostic and Statistical Manual of Mental Disorders*, 5th Edition (DSM-V). People can experience anxiety when the cingulate gyrus, an area of the brain surrounding the deep limbic system, is damaged. The basal ganglia help to integrate thoughts, feelings and movements, as well as help set and interpret anxiety levels. This area is also involved with experiencing feelings of pleasure. Problems associated with the cingulate can be related to struggles with stress, anxiety and related symptoms such as insomnia, stomachaches and muscle tension.

Attention Deficit—New research suggests brain injury may also be a cause of attention deficit disorder (Subhulakshmi, 2015). This can come about following exposure to toxins or physical injury. Head injuries can cause ADD-like symptoms in previously unaffected people, perhaps due to frontal lobe dysfunction or damage, resulting in impairment of executive functioning. However, further research connecting brain trauma with attention deficit disorder is needed.

The DSM-V describes attention deficit disorder as a persistent pattern of inattention that interferes with functioning and development, characterized by inability to give close attention to details, difficulty sustaining attention in tasks, inability to listen when spoken to directly, inability to follow through on instructions, failing to finish work and difficulty organizing tasks and activities, especially sequential tasks. More succinctly put, it is the inability to focus your thoughts and attention.

Balance—Sometimes traumatic brain injury can cause balance and equilibrium problems. Balance problems after head trauma can fall under either peripheral or central injuries. Central injuries refer to injury of the central nervous system structures having to do with balance and coordination including the cerebellum and the brainstem. Peripheral injuries refer to injury to the inner ear structure or the VIIIth Cranial Nerve, which is the cranial nerve that carries information from the ear (including the inner ear) to the brain. There are also issues, which are considered sensory problems, as they are associated with the parts of the brain that govern vision and hearing. Midline shift syndrome, in which balance and equilibrium are affected, generally goes hand-in-hand with post-trauma vision syndrome. Symptoms of midline shift syndrome and other balance disorders include:

- Continual sense of disequilibrium
- Difficulty maintaining balance
- Incorrect weight distribution and posture
- Inappropriate gait
- Trouble walking in a straight line

Patients of midline shift syndrome frequently also complain that the walls seem to be moving in on them, or the horizon is oddly tilted.

Behavior Problems—Symptoms of brain injury can appear in a wide range of previously rare behavior. Examples include:

- Aggression toward others
- Aggression toward self

- Tantrums and crying
- Yelling and cursing
- Explosive anger
- Non-compliance
- Property destruction

Bipolar—A mood disorder somewhere on the spectrum between depression and schizophrenia and marked by severe fluctuation of manic episodes. Several studies have shown a link between people with bipolar and other psychiatric disorders with head trauma (Silver, Kramer, Greenwald, & Weissman, 2001).

Brain Fog—Brain fog refers to a low degree of delirium where the brain is sluggish with its function. Sometime called "clouding of consciousness," it can be manifested in a wide range of general daily activities, affecting short-term memory, ability to focus and calculate decisions. It is similar to the feeling of being sleep deprived for a few days, or experiencing a severe hangover.

Chronic Fatigue—When the brain is injured, it requires a lot of fuel and energy to heal and find ways to return to normal operation. The unfortunate byproduct can be a sense of fatigue during typical daily activities. Long-term studies are few with this condition, but logic would attribute poor brain health with lack of overall energy, and susceptibility to decline unless medical or lifestyle changes intervene.

Cognitive Difficulty—Cognitive issues are any issues related to thinking. These problems can be relatively mild and can improve over time, or they can be more severe, long-term issues that make it difficult to live independently. Cognitive thinking includes being aware of one's surroundings, being able to pay attention, concentrate, short-term memory, reasoning, problem solving and executive skills such as goal setting, planning, initiating, self-awareness and self-monitoring and evaluation. Typically, cognitive difficulty arises from trauma to the frontal lobes, or prefrontal cortex.

Comorbidity—In psychiatry, psychology and mental health counseling, comorbidity refers to the presence of more than one diagnosis occurring in an individual at the same time. However, in psychiatric classification, comorbidity does not necessarily imply the presence of multiple diseases, but instead can reflect our current inability to supply a single diagnosis that accounts for all symptoms.

Depression—Prolonged sadness may be a symptom of any number of circumstances in life, brain health included. A brain diminished in functioning either from concussion, being severely shaken, other trauma or degenerative disease may not have normal aptitude for resilience to deal with events of life.

Language and Speech—Language-related difficulties can develop from traumatic brain injury. Problems can be the result of damage to areas that govern communication in the brain, or they can be the result of motor problems or weaknesses. Examples include various forms of aphasia, which affects both comprehension and production of speech, as well as the ability to read and write. Language difficulties relating to motor problems include: apraxia, exhibited with difficulty coordinating mouth and speech movements; and dysarthria, the individual can think of the right words to use but neurological damage prevents him or her from using the muscles needed to form the words.

Memory and Learning—Immediate recall, otherwise known as "short-term" memory, as well as "long-term" memory, which refers to information stored for extended durations, may be affected by brain trauma. Thought to be like a super-computer with files of information, the brain stores memories much differently, typically encoding neural connections giving the brain the ability to recall information and experiences. Memory and learning are related, and remain fascinating subjects of research. Still, we know memory fades over time, and memory loss may be accelerated by brain trauma and lifestyle.

Parkinson's Disease—Another human brain disorder that may be connected to brain trauma is Parkinson's disease, a motor system disorder affecting more than 500,000 Americans. A study conducted in 2011 by UCLA researchers found that while a traumatic brain injury does not cause Parkinson's, it can make the brain more susceptible to the neurodegenerative disorder (Hutson et al., 2011). Parkinson's affects roughly 1 percent to 2 percent of the population over the age of 65.

The disease is characterized by tremor, rigidity, slowness of movement and impaired balance and coordination. It occurs when neurons in certain sections of the midbrain die or become impaired. The neuronal loss causes a decrease in the level of an excitatory neurotransmitter, which causes the neurons in another part of the brain to initiate aberrant neural impulses. Genetic factors may play a stronger role in some forms of the disease, while environmental factors play a prime role in other forms.

Sleep Disorders—Brain trauma may interfere with the sleep process resulting in fatigue felt in the brain and body. My practice has taken sleep very seriously, treating patients with sleep apnea, fatigue, restless leg syndrome, chronic insomnia and narcolepsy. Without deep sleep, the brain and body malfunctions, like an engine without fuel. Concussions can affect sleep negatively, which is ironically the best way to heal from the trauma.

The repercussions of concussions can be deadly, dangerous and can start or exacerbate any number of pre-existing conditions with long-term impairments. The next time you hear someone say, "You got your bell rung," it will not illicit casual banter about being tough and getting back in the game. Instead, take it as serious as a heart attack.

Post-Concussion Treatment: Healing from Concussion during the First 30 Days

Immediately after a concussion occurs, the brain begins the healing process. Over the course of the next few days and up to about 30 days, it is critical to accept my treatment strategy and do . . .

Nothing.

The brain physiology, blood flow and neuronal pathways all need to rest. Particularly during the first 24–72 hours, I recommend minimizing any activity that provokes the symptoms of concussion. This includes physical and mental stimulation that may interrupt the healing process by forcing the brain to work. I use the phrase "brain sprain" because like an ankle sprain, you have to limit movement so the muscles, tendons and ligaments get a chance to return to normal before adding any more pressure to the wound.

During the acute phase, meaning the period of time immediately following a concussion injury, the brain requires rest while dealing with a metabolic demands of repairing the affected brain cell membranes that have been stretched. PET scan studies show that glucose, the primary energy source, is not able to freely get into the brain cells as usual, preventing the cell's ability to get the fuel to supply the demand for repair or proper functioning into the cell. In other words, the damaged brain cells are grasping for energy, but they cannot get the fuel.

Thus the need for rest, as well as healthy foods, plenty of water and perhaps nutritional supplements—all support the healing process.

Immediate recommendations include: within a day or two of the concussion, while symptomatic at rest, do not jog, run, lift weights or do any kind of physical exercise because it pumps more blood into the "leaky" brain cells that are trying to heal. Also, avoid any mental activity like reading, writing, texting, learning, even talking. Avoid the sunlight or well-lit rooms when sensitive, because the eyes and nervous system pathways that take in visual stimuli may also be affected. Even watching movies, playing video games, loud music, working on the computer or trying to fix something may all exasperate the concussion healing. The brain is involved with everything we do, so for the first day or two, just rest.

When the initial symptoms have dissipated, that does not mean the concussion has healed and the athlete is ready for action or the classroom. Now we move into a phase I refer to as "relative rest," minimizing mental and physical stimulation until the athlete is symptom free during activity. "Relative rest" refers to gradually liberalizing mental or physical activity, still avoiding those that provoke the athlete's concussion-related symptoms.

Once the injured player is free of symptoms at rest, I begin a 5-Step Progressive Exertion recovery guide which is built into XLNTbrain Sport™ that monitors symptoms, and guides the timeline for a return to practice and game play.

During this recovery phase, each day presents tasks with increased levels of difficulty. Should any of the concussion symptoms reappear, then it is back one day, to the previous level of activity which did not provoke symptoms.

However, if the athlete progresses each day through recovery without provoking any symptoms, then the brain is healing from the trauma. When the athlete can complete all the "5 Steps" of the Progressive Exertion plan and their cognitive performance remains at baseline, then they can seek medical permission to return to play.

Typically, this allows for a seven-day cycle. It could vary, and I recommend erring on the side of caution, without rushing the return to normal activity and game play.

One of the reasons recovery time can vary is because athletes with a history of previous concussions may require longer periods of time to heal. A study reported in *Neurosurgery* (Slobounov, Slobounov, Sebastianelli, Cao & Newell, 2007) indicated the presence of long-term residual visual-motor disintegration in concussed individuals with normal neuropsychological measures. Most importantly, athletes with a history of previous concussion demonstrate significantly slower rates of recovery of neurological functions after the second episode of mTBI (Slobounov et al., 2007).

Many other factors influence the concussion recovery time in addition to previous history of concussion, including the severity of the concussion, level of pain and personal lifestyle factors such as history of drug and alcohol use, exposure to toxic environments, previous brain-related impairments, even genetic history. Every brain is different, every brain injury varies. Most healthy athletes, however, will see significant improvement within 7 to 10 days following their concussion, with 93–97 percent recovered by day 30.

Relieving Pain

In the first 24 hours after sustaining a concussion, the person should not take any pain medications. A pain medication can "mask" the symptoms, which could allow someone to return to activities with a concussion. As stated, many concussion symptoms will take several minutes, hours or days to arise. After this 24-hour period, should the athlete experience a severe headache, I recommend taking an anti-inflammatory (over the counter) acetaminophen. Naproxen, aspirin and ibuprofen (NSAID-type medications) should not be used at first, as they may increase the risk of bleeding. Beyond this, ask your doctor for help with addressing any other pain.

Sleep

Insomnia is a common post-injury symptom. I recommend a temporary sleep aid. Over the counter remedies are usually made of antihistamines which are sedating for most people and help improve sleep quality. However, it is not uncommon for some people to become more alert with antihistamines, worsening the insomnia. Short-term use of traditional sleep aids is appropriate in this setting. A doctor may even recommend taking imipramine, a tricyclic antidepressant, which not only helps with sleep but also can help protect against headaches and improve cognitive performance.

Post-Concussion Recovery Recap

Post-concussion symptoms typically last about 7 to 10 days, depending on how severe the concussion is and other factors. Most people get better within a week. However, that varies based on how well they adhere to the recovery protocol.

General advice for treating a concussion includes the following:

- Sleep—Contrary to some common belief, sleep is the first and best thing to do to help recover from a concussion. Try to get at least 7–8 hours of sleep per night within the first week of sustaining a concussion.
- Mental Rest—The brain needs to rest while it is recovering. Avoid strenuous mental activities during the first few days after sustaining a concussion to avoid provoking symptoms. Limit reading, writing, texting, using computer and playing video games. Also, avoid other visual and auditory stimulus like bright lights and loud music.
- Physical Rest—Engage in no physical exercise until symptom free. Exercise adds strain on the brain, delaying the healing process.
- Eat Healthy—The brain needs a nutritional diet and perhaps some nutritional supplements, such as Omega 3 fatty acids, medium-chain fatty acids, Vitamin B Complex, Vitamin E, CoQ10 and other brain healthy supplements to enhance the healing process.
- Drink Water—The brain needs water to facilitate returning to proper balance. Aim for 100 oz per day.
- Avoid toxins, such as drinking alcohol, and smoking.
- Ease into normal activities slowly, not all at once. Follow my Recovery Protocol for guidance about when to return to the sport or school.
- Make sure to let employers or teachers know that you had a concussion.
- Avoid activities that could lead to another concussion, not only sports, but also certain amusement park rides or (for children) playground activities.
- Avoid driving, operating machinery or riding a bike (since a concussion can slow one's reflexes).
- If necessary, discuss whether it is possible to return to work gradually (for example, starting with half-days at first). Students may need to spend fewer hours at school, have frequent rest periods, or more time to complete tests.
- Take only those drugs approved by the doctor.
- For some people, an airplane flight shortly after a concussion can make symptoms worse.

Fortunately, 50 percent of all concussions will resolve within 10 days, and 93 percent will resolve within 30 days. The small minority whose symptoms are prolonged need added support and care to assist them in returning to normal life activities. It is in this group that I feel that neuromodulatory technology has a particularly helpful therapeutic role.

Rewarding the Brain for Peak Performance

Neurofeedback refers to an operant conditioning technique in which an individual's EEG is monitored and analyzed in real time, and certain patterns of electrical brain activity are rewarded using visual, auditory and sometimes tactile feedback. Rewarding these patterns makes them more likely to occur. Changing, or modulating, the electrical activity of the brain has been shown to have therapeutic and performance benefits. Neurofeedback has been applied in a variety of clinical conditions including attention deficit disorder, anxiety, insomnia and traumatic brain injury. Over the last 40 years, different strategies of neurofeedback have evolved as computer hardware and software technology advanced in the real-time analysis of the EEG activity. In describing the strategies of developing a neuromodulation treatment protocol, I like to use the analogy of planning a trip to the beach. If you have never been there, there are three ways you can find your way. The first is that you can ask someone who has been there before. Over 40 years, neurofeedback providers and clinicians have published their anecdotal and evidence-based findings describing protocols that have therapeutic and performance enhancing benefits. Protocols which reward faster rhythms and inhibit slower rhythms, for example, are shown to improve focus and attention functions. Other protocols rewarding slower EEG patterns have a relaxation effect. By assessing the condition of the individual, the neurofeedback provider can choose the protocol including the region of the brain to be trained to suit the needs of the individual.

The second way you can plan a trip to the beach is to buy a map. As the technology of EEG analysis developed in parallel to neurofeedback, it became possible to map EEG patterns in two-dimensional and three-dimensional space and compare an individual's EEG statistically to a normative database. By identifying regions of brain dysregulation and correlating these regions to symptoms, the neurofeedback provider is able to design a protocol specific to the needs of the individual, implement the reward and inhibit protocols as guided by the maps.

The third way you can plan a trip to the beach is to buy a GPS. The GPS will give real-time feedback and provide corrections should one make wrong turns on the way to the destination. Recent advancements in neurofeedback have integrated the mapping technology of QEEG analysis with the real-time reward feedback of neurofeedback. The neurofeedback practitioner again matches the regions of brain dysregulation to the symptoms of the client. After selecting brain regions of interest, neurofeedback software provides feedback rewarding more normal brain activity by real-time comparison of the EEG to the normative database. This type of training is often referred to as "live Z-score training."

Guiding the Brain to Peak Performance

An exciting new technology aimed at guiding the brain towards improved performance is emerging. Transcranial magnetic stimulation is a technique in which pulsing magnetic energy is applied to selected regions of the brain. This magnetic energy induces electrical currents that activate or inhibit neuronal activity where the magnetic pulses are applied. The frequency patterns and brain locations are guided by QEEG mapping and the correlation of the regions of dysregulation with symptoms.

Case Examples

The following cases illustrate how neuromodulatory technology can be applied to assist in the resolution of symptoms related to mTBI and prolonged post-concussion syndrome.

A Motor Vehicle Accident

TW was 43 years old at the time of his motor vehicle accident. He was the belted driver of a car that was hit from the driver's side by another car that had run a red light. His head struck and broke the side window. He briefly lost consciousness at the time of the accident, and upon regaining consciousness he was confused, disoriented and exhibited both anterograde and retrograde memory loss. He immediately complained of headache and nausea. Imaging of the brain in the emergency room was normal. TW developed prolonged post-concussion symptoms that consisted of cognitive fogginess, memory problems, chronic headaches, personality changes and emotional dysregulation including depression and marked anxiety. He had been to several physicians and had tried several medications including antidepressants, headache treatments and attention deficit disorder medications with limited benefits.

Narrowband Spectra

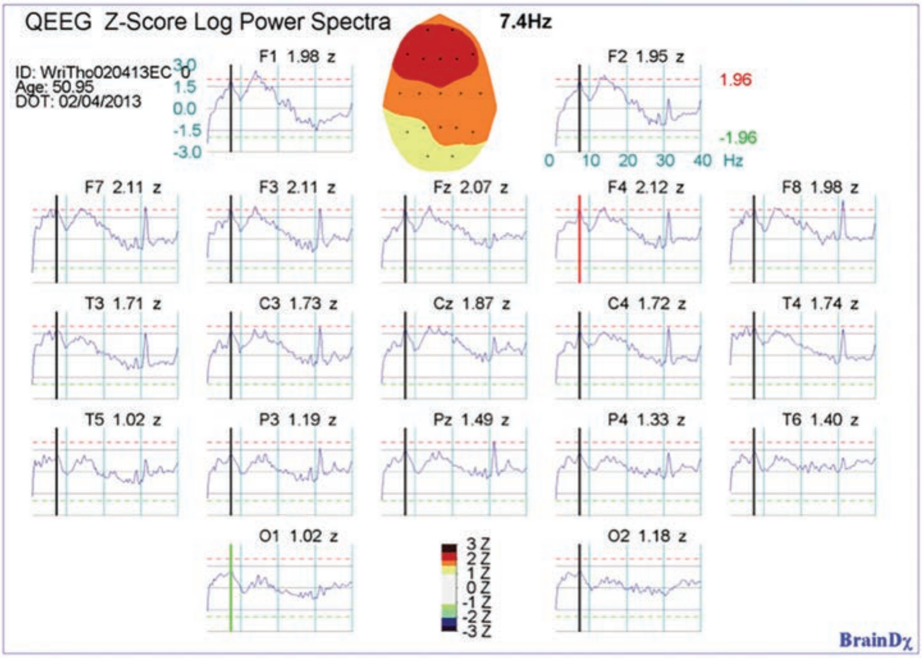

Figure 11.1 The high resolution frequency spectra are shown below at each scalp location for QEEG Z-Score Log Power Spectra. The cursor is at 7.42 Hz.

Narrowband Spectra

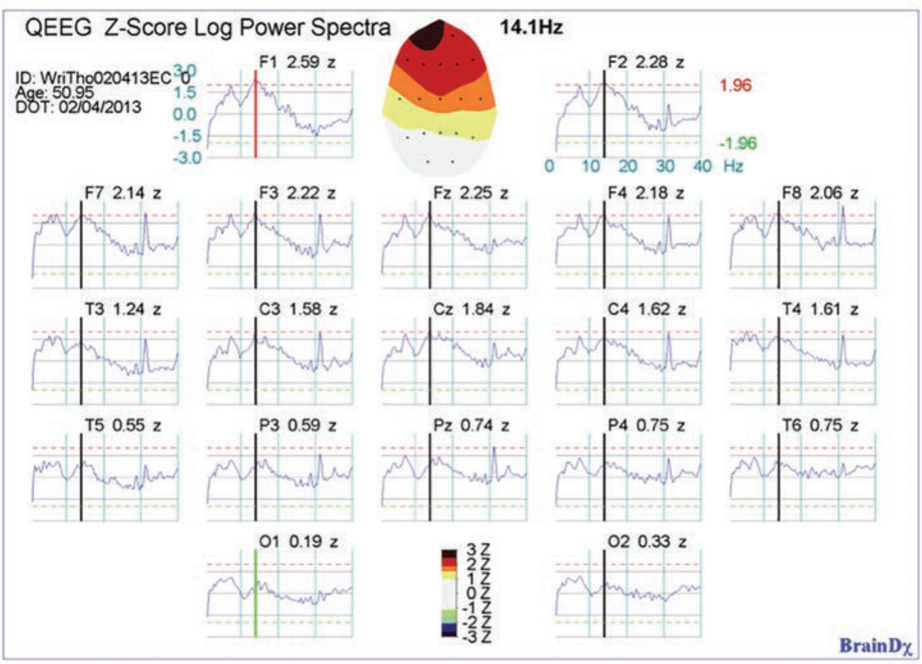

Figure 11.2 The high resolution frequency spectra are shown below at each scalp location for QEEG Z-Score Log Power Spectra. The cursor is at 14.06 Hz.

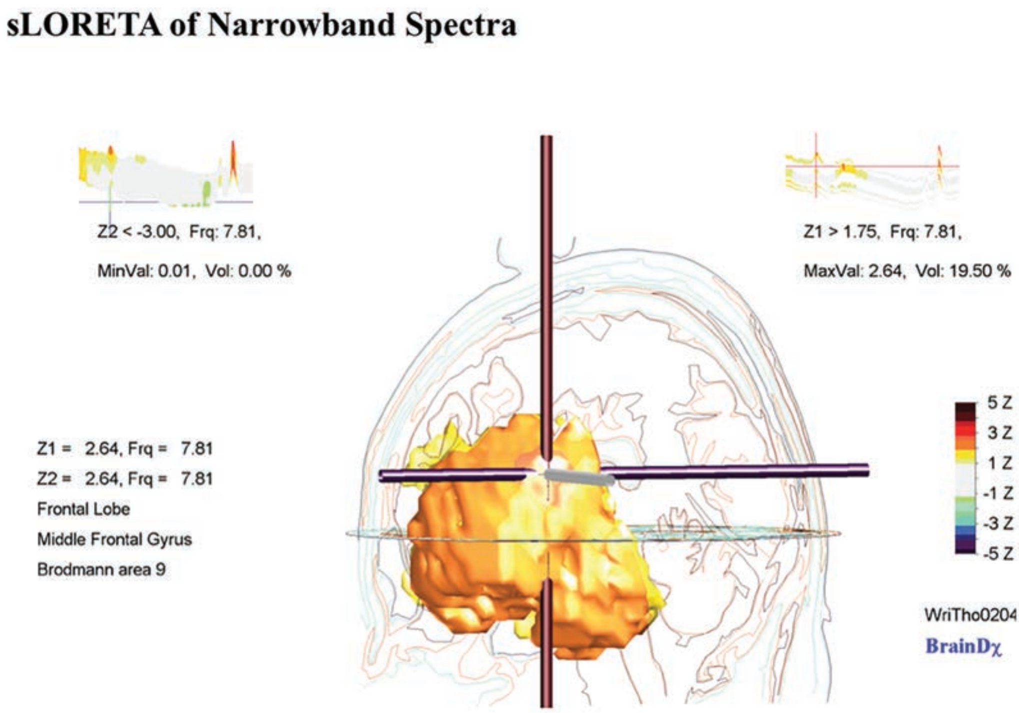

Figure 11.3 sLORETA pre-treatment excess frontal alpha following motor vehicle accident (MVA).

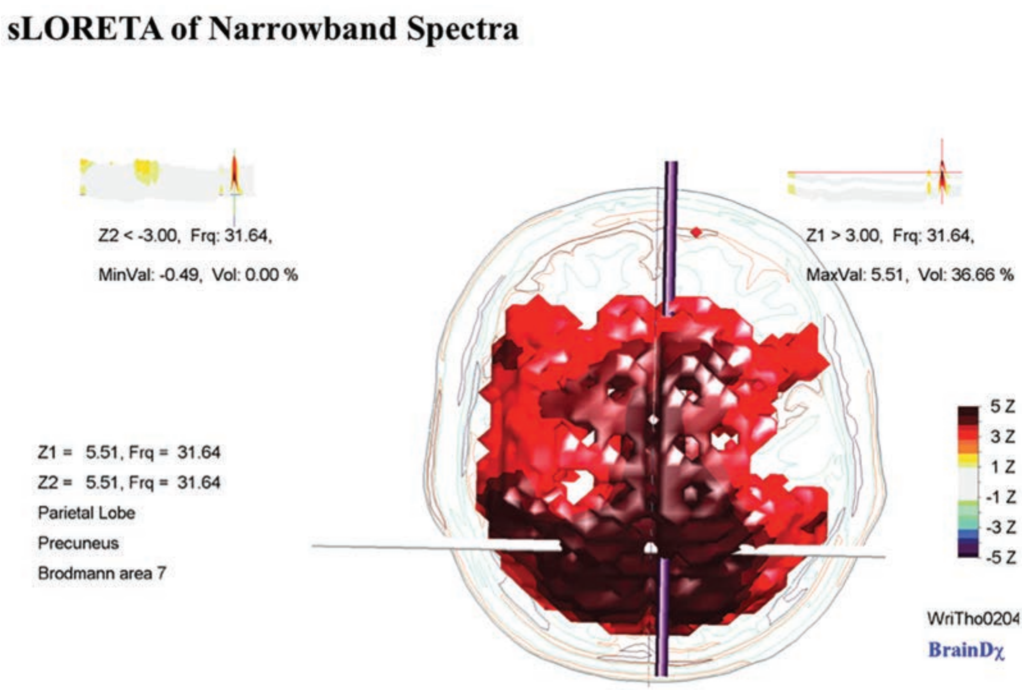

Figure 11.4 sLORETA pre-treatment excess beta in parietal and precuneus following MVA.

TW came to our clinic about six years after his motor vehicle accident. Initial QEEG analysis demonstrated theta and beta dysregulation in the frontal regions correlating with his symptoms of dysregulation of executive function described above. sLORETA current source density analysis demonstrates lateralization of the increased theta activity to the left frontal region. Increased gamma activity is noted on sLORETA current source density analysis in the midline frontal and parietal regions, including the cingulate and precuneus regions corresponding to his symptoms of marked anxiety. His alpha peak frequency was borderline slow at 8.2 Hz.

Based on TW's symptom correlations with QEEG dysregulation, he was treated with sessions of sLORETA live Z-score training for frontal lobe regions of interest that generates rewards when the real-time EEG analysis detects more normal brain patterns. Transcranial magnetic stimulation at 10 Hz over the left frontal and temporal regions was included to address his anxiety and depression. After 20 sessions, TW reported a dramatic resolution of his symptoms. He no longer complained of headaches. His work performance improved dramatically. His cognitive fogginess cleared, and his depression and anxiety improved markedly. His wife was nearly in tears as she described that she had gotten her husband back after six years. QEEG analysis after treatment demonstrated a normalization of the peak alpha frequency to 9.4 Hz, improvement of the theta and beta frontal dysregulation and complete resolution of the increased gamma activity noted in the midline frontal and parietal regions.

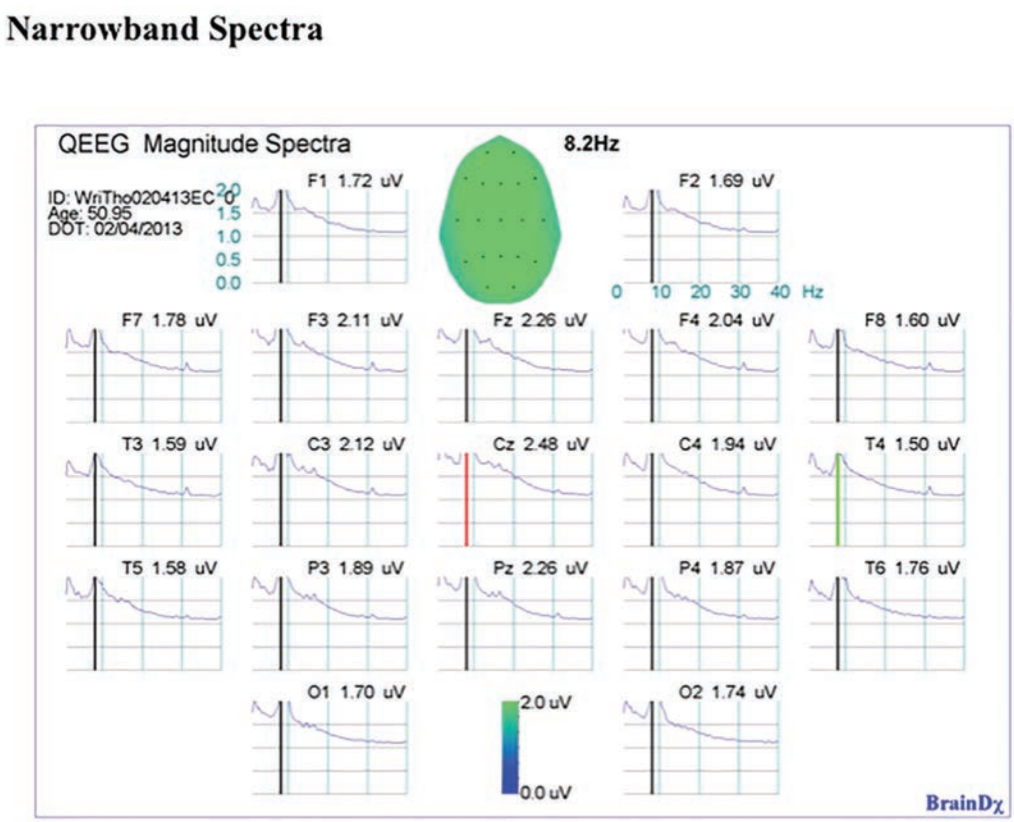

Figure 11.5 The high resolution frequency spectra are shown at each scalp location for QEEG Magnitude Spectra. The cursor is at 8.20 Hz.

Narrowband Spectra

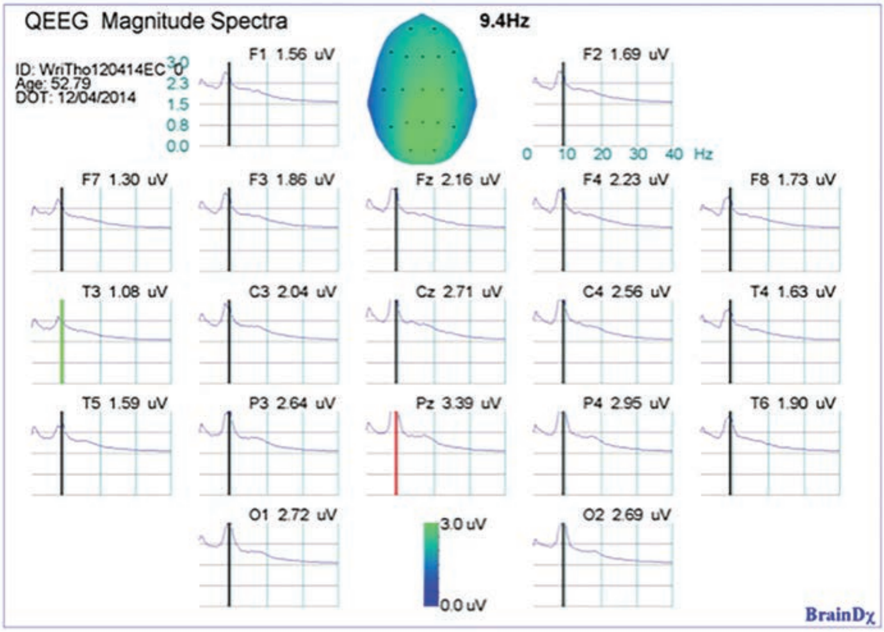

Figure 11.6 The high resolution frequency spectra are shown at each scalp location for QEEG Magnitude Spectra. The cursor is at 9.38 Hz.

Narrowband Spectra

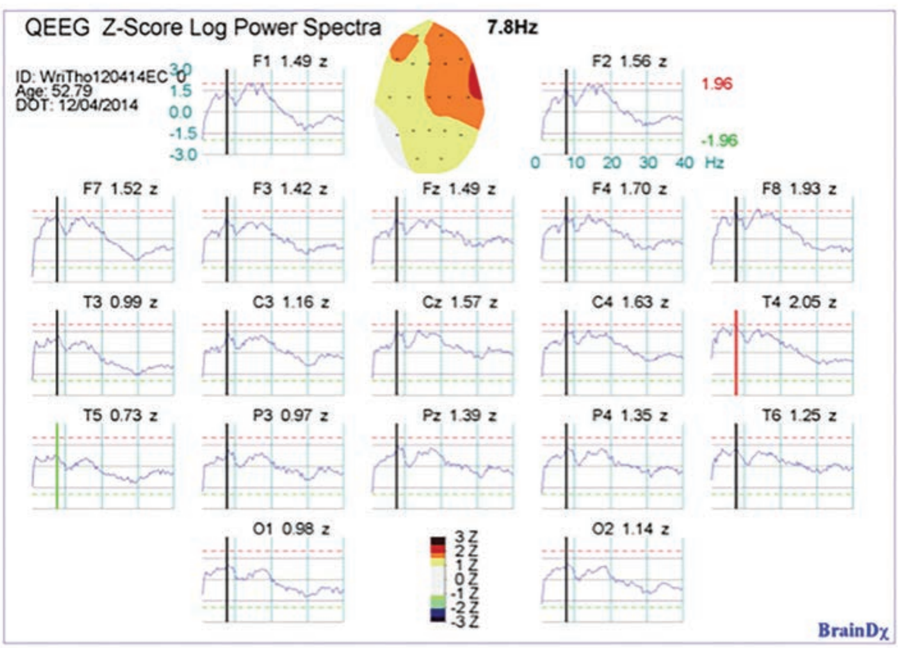

Figure 11.7 The high resolution frequency spectra are shown at each scalp location for QEEG Z-Score Log Power Spectra. The cursor is at 7.81 Hz.

Narrowband Spectra

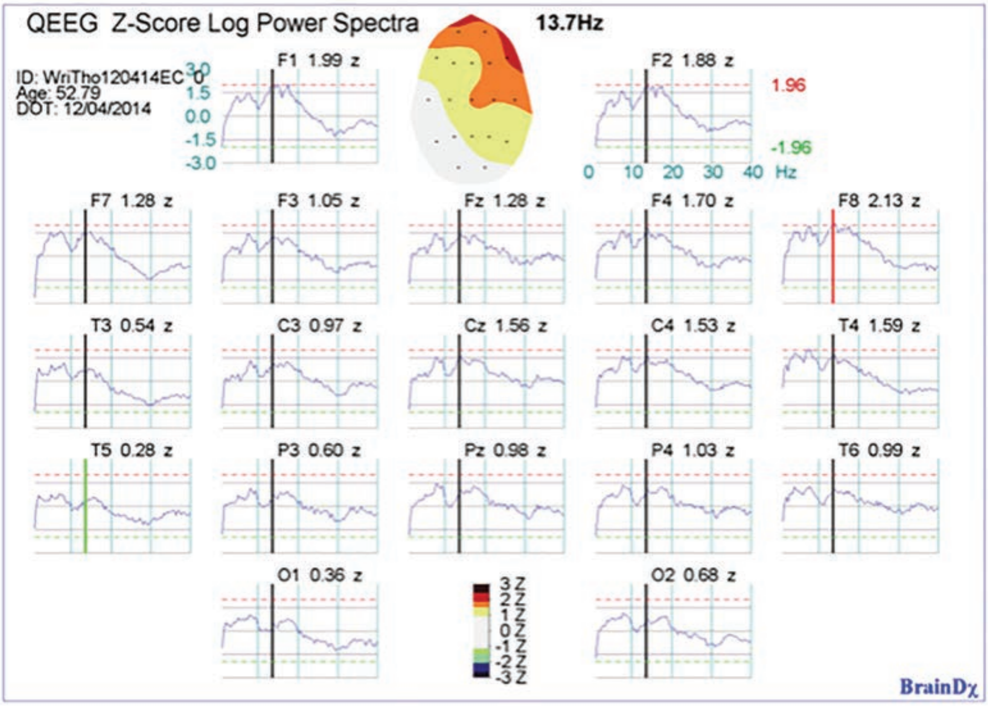

Figure 11.8 The high resolution frequency spectra are shown at each scalp location for QEEG Z-Score Log Power Spectra. The cursor is at 13.67 Hz.

sLORETA of Narrowband Spectra

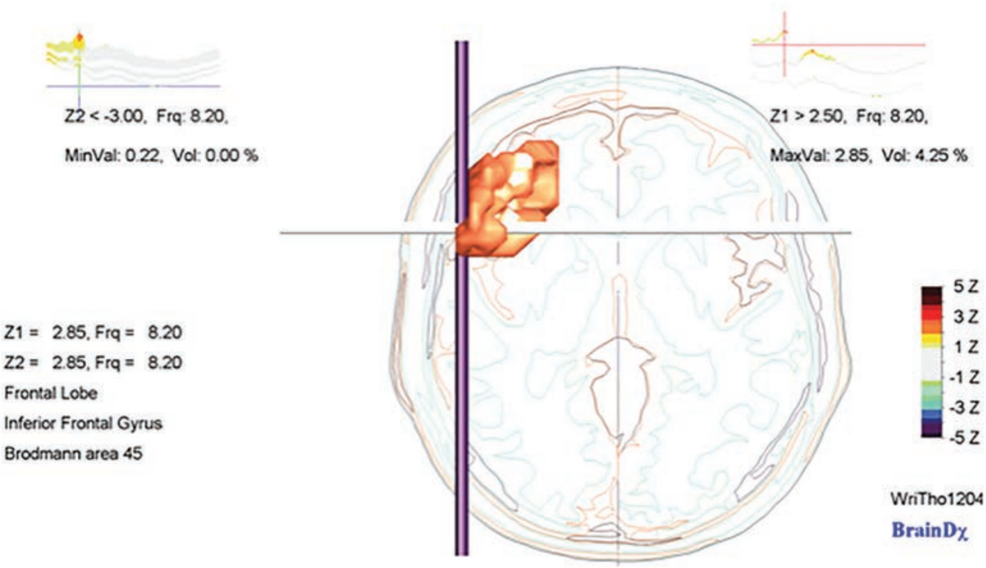

Figure 11.9 sLORETA post-treatment reduced frontal alpha after live Z-score training following MVA.

Case of Emotional Incontinence

BR was 57 at the time he sustained a falling injury at work. He fell backwards off a two-foot ledge striking his hardhat protected head against concrete. He did not lose consciousness, but immediately experienced headache and neck pain. In the days that followed the accident, BR complained of sensitivity to light and sound, headache, nausea, sleeplessness and marked personality changes. He was short tempered, and unable to control his emotional outflow. In casual conversation, if the subject turned to one of even the most minimal sadness, his eyes would often well up with tears and he would become overwhelmed with crying. Less often, he would blurt out with inappropriate laughing at things that were only marginally funny. Neurologists term this emotional incontinence "pseudo-bulbar affect," referring to the fact that emotional outflow is no longer being regulated by frontal lobe inhibition. BR also complained of being easily overwhelmed by complex environments, social settings and conversations in which several people were speaking at the same time. When he came to our clinic several months later, BR's post-concussion symptoms largely resolved, with the exception of the emotional incontinence and intolerance of complex environments. He had become increasingly depressed and socially withdrawn. Initial QEEG analysis demonstrated increased theta activity in the frontal regions, lateralized to the right, along with generalized hypercoherence patterns in the theta, alpha and beta bands.

BR was treated with sLORETA live Z-score training with the frontal and temporal lobes targeted as regions of interest along with transcranial magnetic stimulation. After 20 sessions, BR enjoyed a

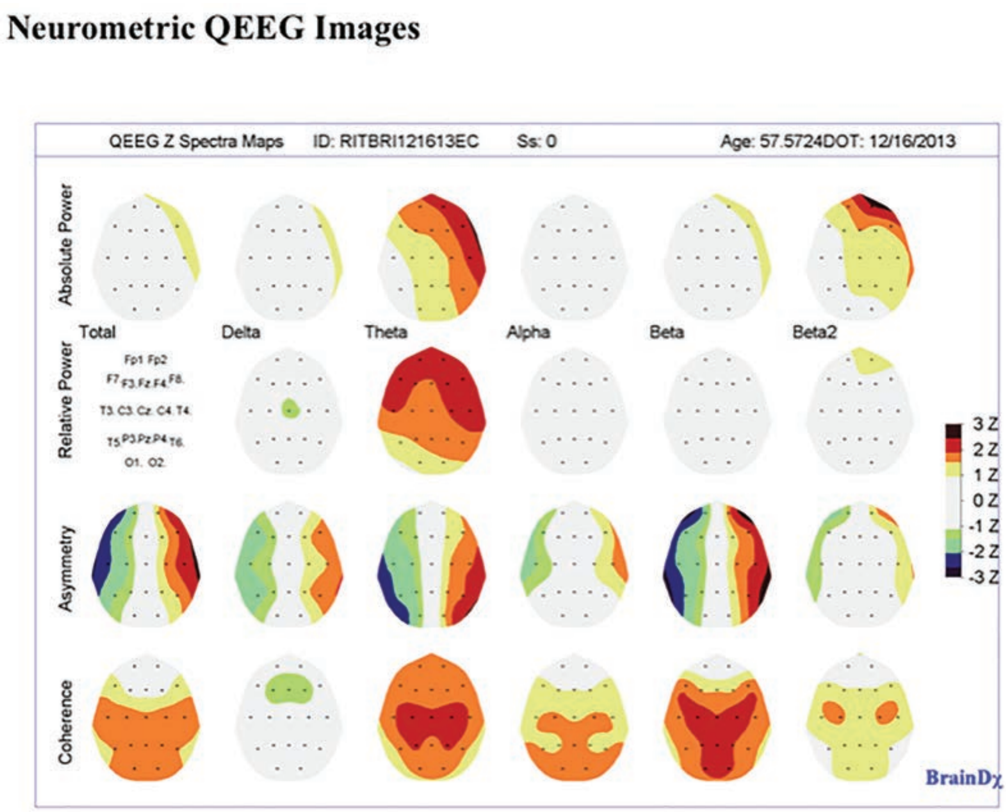

Figure 11.10 A summary of the QEEG results for this patient is provided by these topographic images, displaying the Z-scored features computed from 19 standardized electrode positions, as viewed from above with the nose at top, and left on the left. The scale is set at +/− 3.0 Z.

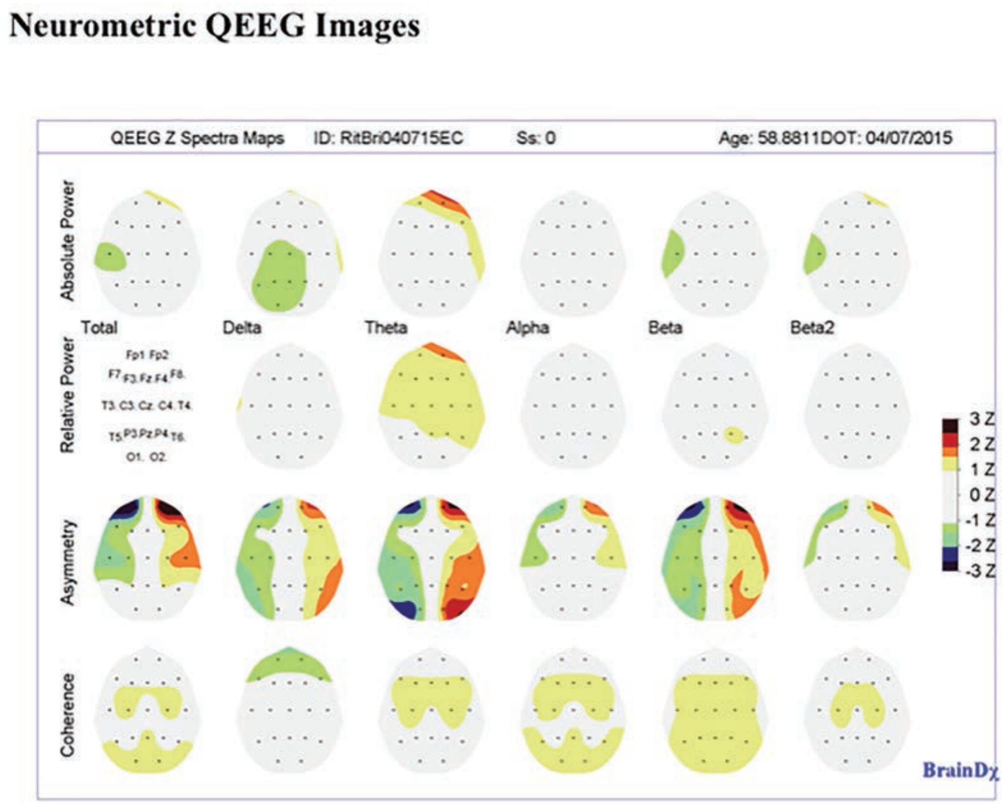

Figure 11.11 A summary of the QEEG results for this patient is provided by these topographic images, displaying the Z-scored features computed from 19 standardized electrode positions, as viewed from above with the nose at top, and left on the left. The scale is set at +/− 3.0 Z.

marked improvement in his symptoms of emotional incontinence. He was able to carry on entire conversations without uncontrolled emotional outflow. He was able to tolerate complex social environments much better, and was less reclusive. Follow up QEEG analysis demonstrated a dramatic improvement in the frontal theta activity and the broad-spectrum coherence.

The Train Wreck

AC is a porter for a railroad company. One day he was sitting in a seat in an empty passenger car that was being coupled to the train. The car and train collided at medium velocity and AC was thrown forward and recoiled back striking his head against the headrest. He had immediate global headache, followed by fatigue and cognitive impairment. He was amnestic for the event. In the weeks that followed, he suffered from excessive daytime sleepiness and intermittent insomnia. He had difficulty concentrating and memory problems. Crowds and bright light overwhelmed him. A CT scan of the head done at the ER was normal.

Analysis of AC's QEEG performed six months after his injury demonstrated increased delta band activity in the occipital and parietal regions with a faster than expected alpha rhythm of 11.7 Hz. This likely represents disruption of the physiology of the default mode network (DMN), the regions of the brain that are most active when cognitive activity is least active. Neurofeedback

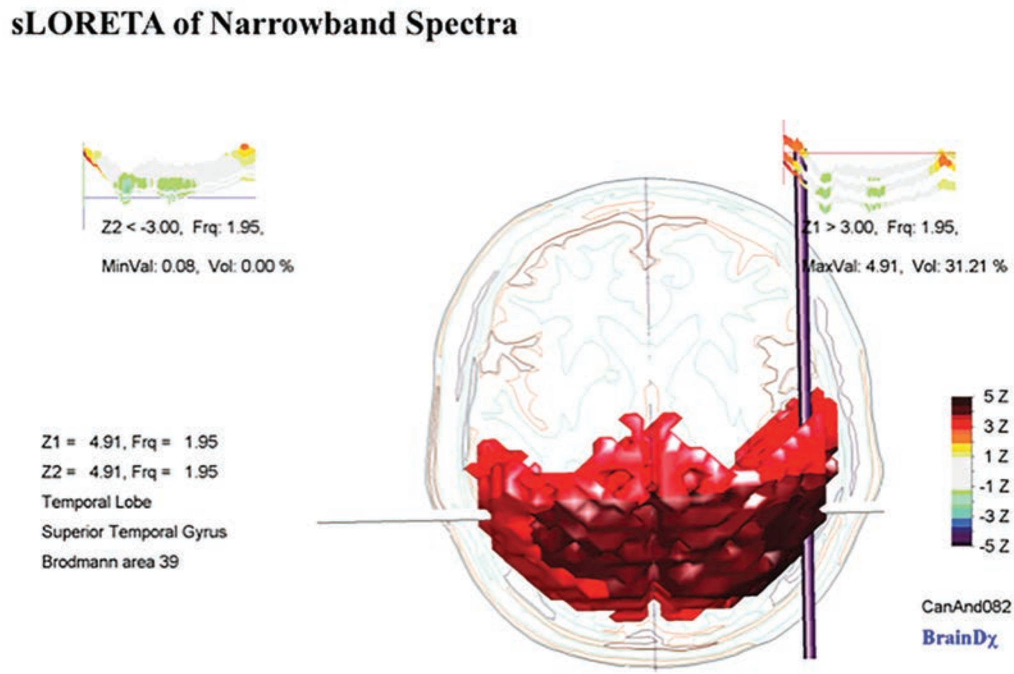

Figure 11.12 sLORETA pre-treatment excess posterior delta following train accident.

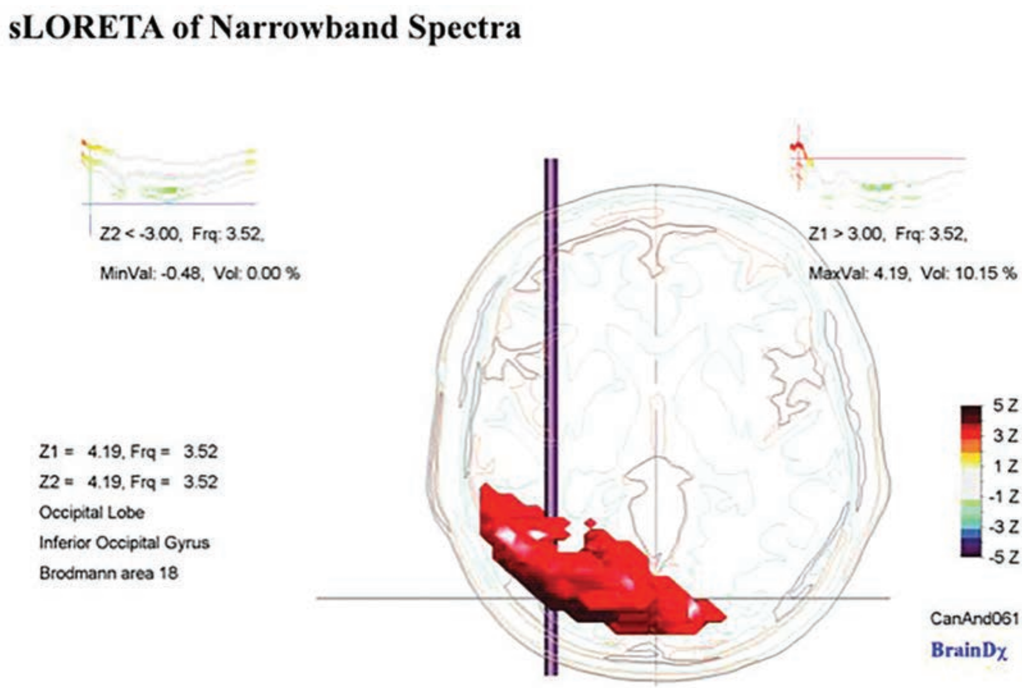

Figure 11.13 sLORETA post-treatment showing reduced posterior delta following train accident.

training focused on bringing the default mode network back online using sLORETA live Z-score training with the DMN and precuneus as training regions. After 20 sessions, AC reported a marked improvement in his focus, daytime alertness and headaches. Post-neurofeedback QEEG analysis demonstrated improvement in the posterior delta activity and the alpha rhythm frequency coming down to 9.4 Hz.

Summary

Although generally self-limited, concussion/mTBI can have long-term and quite serious consequences in a small minority of victims. These consequences include prolonged post-concussion symptoms such as headaches, cognitive disturbances, balance problems, sleep-related complaints and mood dysregulation. Repeated concussions are typically slower to heal and carry along the more serious risks of early Alzheimer's Disease, Chronic Traumatic Encephalopathy, Parkinson's and, rarely, Amyotrophic Lateral Sclerosis. Initial post-injury treatment consists of physical and cognitive rest, combined with symptomatic medication treatment. For those individuals with prolonged post-concussion symptoms, neuromodulatory interventions such as neurofeedback and transcranial magnetic stimulation can be effective interventions, even in cases that fail medication management.

References

American Association of Neurological Surgeons. (2011). Concussion. Retrieved Dec. 2, 2015 from http://www.aans.org/Patient%20Information/Conditions%20and%20Treatments/Concussion.aspx

Bradley, B. (2013, October 29). George Mason researchers think saliva might unlock concussions. Retrieved Dec. 3, 2015 from http://www.nfl.com/news/story/0ap2000000271940/article/george-mason-researchers-think-saliva-might-unlock-concussions

Fakhran, S., Yaeger, K., Collins, M., & Alhilali, L. (2014). Sex differences in white matter abnormalities after mild traumatic brain injury: Localization and correlation with outcome. *Radiology, 272*(3), 815–823.

Giza, C., Kutcher, J., Ashwal, S., Barth, J., Getchius, T., Gioia, G., . . . Zafonte, R. (2013). Evidence-based guideline update: Evaluation and management of concussion in sports. *Neurology, 80*(24), 2250–2257.

Guerriero, R., Proctor, M., Mannix, R., & Meehan, W. (2012). Epidemiology, trends, assessment and management of sport-related concussion in United States high schools. *Current Opinions in Pediatrics, 24*(6), 696–701. doi:10.1097/MOP.0b013e3283595175

Halstead, M., Walter, K., & The Council on Sports Medicine and Fitness. (2010). Sport-related concussion in children and adolescents. *Pediatrics, 126*(3), 597–615. doi:10.1542/peds.2010–2005. Retrieved Dec. 3, 2015 from http://pediatrics.aappublications.org/content/126/3/597

Hootman, J., Dick, R., & Agel, J. (2007). Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *Journal of Athletic Training, 42*(2), 311–319.

Hutson, C., Lazo, C., Mortazavi, F., Giza, C., Hovda, D., & Chesselet, M. (2011). Traumatic brain injury in adult rats causes progressive nigrostriatal dopaminergic cell loss and enhanced vulnerability to the pesticide paraquat. *Journal of Neurotrauma, 28*(9), 1783–1801. doi:10.1089/neu.2010.1723

Kerasidis, H. (2014, August 19). Gender differences complicate concussion care. [Web log post]. Retrieved Dec. 2, 2015, from www.psychologytoday.com/blog/brain-trauma/201408/gender-differences-complicate-concussion-care

Lincoln, A., Caswell, S., Almquist, J., Dunn, R., Norris, J., & Hinton, R. (2011). Trends in concussion incidence in high school sports: A prospective 11-year study. *American Journal of Sports Medicine, 39*(5), 958–963. doi:10.1177/036354651039232

Marar, M., McIlvain, N., Fields, S., & Comstock, R. (2012). Epidemiology of concussions among United States high school athletes in 20 sports. *American Journal of Sports Medicine, 40*(4):747–755. doi:10.1177/0363546511435626. Epub 2012 Jan 27

McCrory, P., Meeuwisse, W., Aubry, M., Cantu, B., Dvorák, J., Echemendia, R., . . . Turner, M. (2013). Consensus statement on concussion in sport: The 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Journal of Science and Medicine in Sport, 16*(3), 178–189.

Mielke, M., Savica, R., MD, Wiste, H., Weigand, S., Vemuri, V., Knopman, D., . . . Jack, C. (2014). Head trauma and in vivo measures of amyloid and neurodegeneration in a population-based study. *Neurology, 7, 82*(1), 70–76. doi:10.1212/01.wnl.0000438229.56094.54

Shahim, P., Tegner, Y., Wilson, D., Randall, J., Skillback, T., Pazooki, D., . . . Zetterberg, H. (2014). Blood biomarkers for brain injury in concussed professional ice hockey players. *The Journal of the American Medical Association Neurology, 71*(6), 684–692. doi:10.1001/jamaneurol.2014.367. Retrieved Dec. 3, 2015 from http://archneur.jamanetwork.com/article.aspx?articleid=1846623

Silver, J., Kramer, R., Greenwald, S., & Weissman, M. (2001). The association between head injuries and psychiatric disorders: Findings from the New Haven NIMH Epidemiologic Catchment Area Study. *Brain Injury, 15*(11), 935–945.

Slobounov, S., Slobounov, E., Sebastianelli, W., Cao, C., & Newell, K. (2007). Differential rate of recovery in athletes after first and second concussion episodes. *Neurosurgery, 61*(2), 338–344.

Subhulakshmi, R. (2015). Diagnosis of ADHD using brain imaging technique: A survey. *International Journal of Science and Research, 4*(6), 1920–1924. Retrieved Dec. 2, 2015 from http://www.ijsr.net/archive/v4i6/SUB155772.pdf