Introduction

Attention-grabbing headlines such as these from the sports news have brought the issue of head trauma and its consequence of traumatic brain injury (TBI) to the collective consciousness of the public sector, even to the White House. President Barack Obama, in a New Republic interview, made the controversial comment that “... if I had a son, I’d have to think long and hard before I let him play football.” Both the medical and legal professions, while already aware of the issues associated with significant head injuries, have refocused upon this problem. Medical organizations are issuing guidelines regarding head injury and sports. For example, the American Medical Society for Sports Medicine made a recent position statement on concussion in sports. The American Academy of Neurology (AAN) has recently published guidelines for the evaluation and management of concussions, replacing those developed in 1997. Further, a Sports Neurology section within the American Academy of Neurology has been developed and a Sports Neurology fellowship was founded at the University of Michigan. Neurologists currently serve on health and safety committees of a number of athletic organizations such as the National Football League Players Association (NFLPA), the National Football League (NFL), the National Hockey League (NHL), the National Basketball Association (NBA), the United States Tennis Association (USTA), the National Collegiate Athletic Association (NCAA), and several state boxing commissions.

In the legal arena, more and more lawsuits are being advanced involving traumatic brain injuries and claims are being asserted on this basis for Social Security Disability and Veterans Administration benefits. Laws have been enacted in most states dealing with sports concussions and their ramifications for young athletes, and the NFL agreed in the summer of 2013 to a $765 million dollar settlement with former professional players who sustained brain injuries while playing the game.

Just how significant a problem is a TBI? Estimates indicate that each year, about 1.6 million people in the United States sustain this form of trauma. Of those individuals, 270,000 are hospitalized while 800,000 are treated yearly as an outpatient. Further, 52,000 of those who sustain TBIs expire and 80,000 sustain severe neurological disability. As expected, the economic costs not only of medical expenses but also of wage loss and diminished productivity are enormous. The Centers for Disease Control and Prevention (CDC) estimate of the economic burden of TBI in 2010, considering both direct and indirect costs, is approximately $76.5 billion.
This introductory chapter provides an overview of the problem of head injury, starting with a discussion of causation, then examining the topic from a historical perspective, and finally concluding with an overview of the anatomy of the head and neck. In addition, a definition of terms used in issues of head trauma will be provided.

**Causes of Head Injury**

As implied by the term, head injury results from trauma to the head, and can be classified as closed or open. In a **closed head injury**, there may be a fracture of the skull, but the coverings of the brain (meninges) are intact. The brain is damaged by impact against the interior of the skull. In an **open head injury**, an object penetrates the skull and breaches the meninges, causing damage to the brain. The resulting brain injury can be diffuse over a widespread area, or focal, concentrated in a localized part of the brain, depending upon the cause.

The causes of head injury are quite varied and depend upon the population. Overall, in the civilian population in the United States, a study of TBIs found the most common causes to be motor vehicle accidents (45%), followed by falls (30%), work-related accidents (10%), recreational injury (10%), and assault (5%). According to the CDC, falls are the leading cause of TBIs, greatest in children aged 0–4 years old and in adults aged 75 years or older. The CDC estimates that annually between 1.6 and 3.8 million concussions occur in the United States, accounting for 5–9% of all sports injuries, and 30% occur between 5 and 19 years of age. Those at particular risk for a TBI include the following:

- Young, single individuals
- Low income, especially ethnic minority
- Prior history of substance abuse
- Prior history of previous TBI

TBIs are now considered the signature injury of military conflict. Within the armed services, from the year 2000 to the first quarter of 2012, a total of 244,217 cases of TBIs were identified. Of these 76.8% were classified as mild, 16.6% as moderate, and 1% as severe. 4% were not classifiable. Explosion with blast injury was the leading cause of TBIs for active duty military personnel on the battlefield. In one study of combat-related posttraumatic brain injury, 45.2% were caused by a direct blast, 35.7% occurred inside a structure or vehicle due to an explosion nearby, 9.5% were due to vehicle crashes, and 9.5% due to combat-related falls.

Amateur and professional athletes in practically every sport are prone to head trauma with an estimated 3.8 million sports-related concussions occurring annually in the United States. In high school and collegiate sports, the highest incidence of concussion occurs among males playing collegiate football (3.02/1,000 games), followed by men’s college ice hockey (1.96/1,000 games), and women playing collegiate soccer (1.8/1,000 games). The lowest incidence is in women’s high school baseball/softball (0.04/1,000 games). Among professional football players, a study conducted between 1996 and 2001 of the NFL teams revealed 0.41 concussions per game with quarterbacks at greatest risk followed by wide receivers, tight ends, and the defensive secondary.

These and many similar studies demonstrate that head trauma is pervasive throughout society with significant medical, economic, and legal ramifications.

**A Historical Perspective**

Ever since recorded history, the consequences of head trauma have been recognized and treated by mankind. It is interesting to see how concepts that we consider fairly basic were revolutionary in scope and understanding to scientists and physicians during these early times.

**Egypt** Our knowledge of ancient Egyptian medicine is mostly limited to the Edwin Smith Papyrus, written about 1650–1550 BC. This document describes several cases of gaping head wounds, skull fractures, and resultant neurological deficits.
Greece The ancient Greeks were the first to believe that the brain controlled the workings of the body and housed the soul.17 This understanding led to concern about head trauma and they documented the consequences of brain injury, especially through the writings of Hippocrates (460–370 BC). There are speculations that he was the first to refer to concussion, identified as *commotio cerebri*, although it is not clear if he was referring to the mechanism of injury, the period of unconsciousness, or the whole spectrum of head injury.16 Further, he describes the approach to treating a skull fracture and operating to “release the accumulated humors or to slacken the tightness of the skull.”16

Rome The Romans also had an appreciation of the importance of a head injury with detailed descriptions,16 particularly through the writings of Celsus (25 BC–50 AD) and Galen of Pergamon (129–216 AD), Galen, who was the physician to the gladiators, described the symptom of dizziness after head trauma.16

Arabia After the fall of the Roman Empire, medicine in the Middle East flourished during the first millennium.16 The Persian physician Muhammad Rhazes (850–923 AD) wrote about concussion and distinguished it from other forms of head trauma, which was a major step in understanding this condition.16 His writings described a concussion as transient loss of function but without brain damage. Other important Arabian physicians writing about head injury were Albuccasis (936–1013 AD) and Avicenna (980–1037 AD).

Renaissance During the medieval period, European medicine and science came to a grinding halt, unlike what was happening in the Middle East. With the dawn of the Renaissance (14th to 17th centuries) in Florence, medical understanding flourished along with concepts of head trauma. The Milan physician Lanfrancus (d. 1306 AD) discussed concussion as being separate from other types of head injury, and postulated that the symptoms could rapidly disappear and resulted from a “transient paralysis of cerebral function caused by the brain being shaken”16 Similarly, Guy de Chaulliac (1300–1368) described the good outcome with a concussion as compared to the more serious consequences of skull fracture and penetrating brain wounds.16

The first description of gunshot wounds to the head16 was provided by the German physician Braunschwig (1497). Thus, the phenomenon of *commotion* to indicate cerebral impairment due to the brain being shaken was distinguished from significant brain damage, leading to the concept of concussion. During the early 16th century, Berengario da Carpi postulated that this *commotion* was due to the soft brain being struck against the hard interior of the skull.16 Likewise, about this time, Ambroise Pare also wrote about *commotio cerebri* in terms of shaking of the brain as a basis for concussion. Other Renaissance writers taking up the definition and characterization of concussion include Coiter (1573), Marchetti (1665), and Fabricius in 1578.16

Age of Enlightenment By the 18th century, scientific advances such as the microscope led to an interest in understanding the mechanism of disease. With the development of the scientific method, medical research was further advanced by measurable and quantifiable observations. With further research, especially the work of Jean-Louis Petit, a concussion was differentiated from a *contusion*, or bruising of the brain.16 Guillaume Dupuytren in 1839 described contusions as many small hemorrhages on the surface of the brain while indicating that concussion occurs without such findings.18

Modern Period With the 19th and into the 20th century came a new dimension to head trauma, that of vague, non-identifiable symptoms. John Erichsen, Professor of Surgery at University College Hospital in London, England published a series of papers regarding “certain obscure injuries of the nervous system commonly met with as the results of shocks of the body received in collisions on railways.”19 Because many were associated with railroad accidents, these injuries became known as “railway spine” or “railway brain” thought to be due to “molecular disarrangement” or “anemia of the spinal cord.” Typical symptoms included headache, dizziness, and memory loss. This topic was a controversial matter, particularly as to whether or not these symptoms were of organic cause. Such skepticism led to the term “compensation neurosis” by Rigler in 1879 since they tended to resolve with compensation for the injury.19 These issues continue to be debated today.

Probably, the most famous patient in the annals of head trauma was Phineas Gage. In 1848, Phineas, while working on a railroad bed in Vermont, was using a tamping iron (measuring 43 inches long, 1 ½ inches in diameter, and weighing 13 pounds) to pack explosive...