Traumatic Brain Injury: Classification, Pathophysiology and Treatment

Youlan Li

1. Introduction

Traumatic Brain Injury (TBI), also known as an intracranial injury, occurs when a sudden, external force or attack acts on the brain. It is a broad term that encompasses the vast range of injuries that happen to the brain. The levels of damage vary from mild injuries such as concussions to severe brain injury that may lead to coma or even death. Traumatic Brain Injuries are classified as primary, indicating that the damage is immediate and occurs instantly. Conversely, other TBIs can be classified as secondary, implying that they may develop over hours, days, or even weeks. These secondary TBIs stem from the initial impact on the head.

On the other hand, brain injuries can also be categorized as penetrating and non-penetrating. Penetrating injuries occur when an object, such as a bullet or a knife, directly goes through the brain. In contrast, non-penetrating happens when external forces, such as those from car crashes, sports collisions, and accidents, or being struck by something, are strong enough to cause movement of the brain or disrupt the normal flow of cerebrospinal fluid within the skull.

Except for physical brain injury results in TBI, emotional trauma could also be a cause of TBIs. The emotional TBIs involve complex interactions between stress hormones (cortisol) and various brain functions, which can lead to alterations in synaptic plasticity. Prolonged elevation of hormone levels hampers neurogenesis, leading to dendritic atrophy and cognitive impairment. Strong emotions can trigger dissociation and brief disruptions in perception and consciousness. For example, PTSD, an emotional trauma, affects the functions of the brain by most impacting the amygdala, hippocampus, and prefrontal cortex, which all play a key role in controlling emotions and responding to fear. The consequences of emotional brain injury might be chronic stress, heightened fear, and increased irritation. According to the data from the Academy for Multidisciplinary Neurotraumatology, 69 million people globally will suffer TBI each year, with a total of 55.9 million people suffering mild TBI each year. Approximately 190 TBI-related deaths happen every day, which demonstrates the wide prevalence of TBIs worldwide and is required to raise people's awareness of this disease.

2. Pathophysiology, Clinical Presentation, and Classification

Based on the levels of damage, there are different brain diseases caused by TBIs. Firstly, mild TBIs, most commonly known as concussions, are usually not life-threatening. When a violent blow, jolt, or bump acts on the head, the brain undergoes a rapid movement, forcefully colliding with the inner walls of the skull. The brain functions get disrupted, usually for a brief period. As a result, further symptoms such as headaches caused by the "pressure" in the head, dizziness, balance problems, deterioration of physical coordination, blurred vision, nausea or vomiting, seizures or even bleeding in or around the brain may develop and occur. For neurological causes, the repetitive high-level rotational forces or sudden stopping leads to the diffusion and stretching of axons, thus the transmission of signals between bundles of axons, commonly referred to as white matter axons, becomes disrupted, leading to alterations in ion concentrations. For instance, the calcium concentration following a concussion starts accumulating, which flows across the synapses into neurons, with a small chance of killing them. There is an abnormal activation of neural circuits. Furthermore, the long-term consequences of concussions are still evident decades after the accident happened. Brain imaging revealed that the victims from the accidents who experienced concussions exhibited significant levels of white matter damage in the frontal lobes, temporal lobes, and hippocampus. In a group of athletes with concussion from a study of a male American football team from NCAA, a reduction of cerebrospinal fluid (CBF), known as hyperfusion, has been observed in the right dorsal midinsular cortex (dmlC) and superior temporal sulcus during the first week after the accident. The CBF in these regions in the majority of cases returned to normal levels within one month, whereas the CBF level in the dorsomedial prefrontal cortex (dmPFC) in others continued to remain below the standard level. The persistent CBF impairment was found to be linked with unfavorable outcomes, as well as symptoms of anxiety and depression.

Going from mild TBIs to more severe TBI: coma, which is a lengthy deep state of unconsciousness, in which the patient's eyes remain closed. Coma could be a result of the scenarios mentioned in concussion, or other conditions such as stroke, lack of oxygen in the brain, infections, and more. The speed at which a brainstem lesion occurs, its location, and its size determine whether it will result in a coma. It is important to note that coma is caused by disordered arousal (level of consciousness) rather than impairment of the content of consciousness. Coma or impaired consciousness occurs due to either or both dysfunction of bilateral cerebral hemispheres/cortex and failure of the reticular activating system (RAS).

The first risk factor, dysfunctions of the cerebral cortex causes brain hemispheres not to respond to stimuli. The following symptoms are closed eyes, pupils not responding to light, no motor responses except reflex movements, irregular breathing, and no responses to painful stimuli. The diffuse axonal injury of white matter due to sudden forces typically results in disruptions

Another major risk factor is the failure of the ascending reticular activating system (ARAS), which is an extensive connection of nuclei and fibers in the brainstem reticular formation (RF) with thalamic nuclei, the basal forebrain, hypothalamus, cerebral cortex, and is responsible for promoting wakefulness and arousal. The circuits connecting the brainstem and cortex enable the brain to regulate transitions between slow sleep rhythms and fast sleep rhythms (as observed in EEG), as well as facilitate attention and the capacity to concentrate.

3. Recovery Rate

According to Beaumont Health, approximately 80% of concussions resolve over 7 to 14 days, 10 days is the average number of days to recover. On the other hand, coma's recovery time varies from days to weeks while some severe cases have lasted several years. The chances of survival depend on the severity of the brain injury such as the original cause of the coma, patients' age, and how long they have been in the state of coma. It's impossible to provide an accurate prediction regarding the person's final recovery, the duration of the coma, or the presence of any long-term issues.

4. Diagnosis and Treatment

In general, the health care professionals would evaluate the level of severity by asking the patients questions about how the injury happened, assessing the person's level of consciousness and confusion, and doing an examination to appraise cognitive abilities, sensory perception, motor skills, and various aspects of brain function, encompassing memory, vision, hearing, touch, balance, coordination, gait, strength, sensation, reflexes, and other relevant indicators. In addition to the evaluation from health care providers, depending on the cause and level of severity, brain imaging methods may be used. Common methods include computed tomography (CT) and magnetic resonance imaging (MRI), which is used to determine whether there is any cerebral hemorrhage or brain swelling.

Similar to the diagnosis, the treatment of TBI also depends on the severity levels. The most serious traumatic brain injuries require specialized hospital treatment and may entail months of inpatient rehabilitation. However, since the majority of traumatic brain injuries are mild, usually a short hospital stay for observation or at-home monitoring followed by outpatient rehabilitation is good.

5. Future Research Directions

According to the Alzheimer's Association, the impact of TBI on cognition is a relatively novel area of research for physicians and researchers. Numerous significant research endeavors are currently in progress to deepen our understanding of injury patterns and brain alterations associated with TBI, as well as to formulate innovative approaches for prevention, diagnosis, and treatment. Consequently, the US National Academies of Sciences, Engineering, and Medicine (NASEM) report suggests the creation and distribution of a TBI classification system that encompasses not just the GCS but also includes brain imaging and additional predictive biomarkers. Patients could undergo periodic reclassification throughout their treatment and recovery phases. A refined TBI classification could include associated conditions resulting from the injury, such as subdural hematoma, skull fracture, or contusion.

6. Conclusion

In summary, this paper provides a comprehensive overview of traumatic brain injury (TBI), covering its classification, diagnosis, treatment, and pathophysiology. TBI's classification is essential for tailoring treatment, emphasizing the need for a comprehensive system that includes imaging and biomarkers. Early diagnosis using advanced neuroimaging techniques is crucial for prompt intervention. The pathophysiology of TBI, from primary mechanical damage to secondary processes, highlights the complexities involved and the need for ongoing research. Treatment involves a range of interventions, emphasizing the interdisciplinary approach required for TBI management.

References

✍️. (2022, August 30). YouTube. Retrieved October 1, 2023, from https://www.alz.org/alzheimers-dementia/what-is-dementia/related_conditions/traumatic-brain-injury?utm_source=google&utm_medium=paidsearch&utm_campaign=google_grants&utm_content=types_of_dementia&gad=1&gclid=CjwKCAjwyNSoBhA9EiwA5aYlbz_RUiOaEFZluQVzAArIXzLf

Brain injuries from concussions still evident decades later. (2020, October 1). National Institute on Aging. Retrieved June 30, 2023, from https://www.nia.nih.gov/news/brain-injuries-concussions-still-evident-decades-later

Coma - Symptoms and causes. (2022, December 14). Mayo Clinic. Retrieved June 30, 2023, from https://www.mayoclinic.org/diseases-conditions/coma/symptoms-causes/syc-20371099

Concussion - Symptoms and causes. (2022, February 17). Mayo Clinic. Retrieved June 30, 2023, from https://www.mayoclinic.org/diseases-conditions/concussion/symptoms-causes/syc-20355594

Estimating the global incidence of TBI. (2022, November 15). AMN • Academy for Multidisciplinary Neurotraumatology. Retrieved June 30, 2023, from https://brain-amn.org/global-incidence-of-tbi/

Get the Facts About TBI | Concussion | Traumatic Brain Injury | CDC Injury Center. (n.d.). Centers for Disease Control and Prevention. Retrieved June 30, 2023, from https://www.cdc.gov/traumaticbraininjury/get_the_facts.html

Keen, S. (n.d.). *Coma - Brain Disorders A-Z*. Brain Foundation. Retrieved June 30, 2023, from https://brainfoundation.org.au/disorders/coma/

Thatcher, T. (2019, February 4). *Can Emotional Trauma Cause Brain Damage? | Highland Springs*. Highland Springs Clinic. Retrieved June 30, 2023, from https://highlandspringsclinic.org/can-emotional-trauma-cause-brain-damage/

Traumatic Brain Injury. (n.d.). Johns Hopkins Medicine. Retrieved June 30, 2023, from https://www.hopkinsmedicine.org/health/conditions-and-diseases/traumatic-brain-injury

Traumatic Brain Injury (TBI) | National Institute of Neurological Disorders and Stroke. (2023, February 7). National Institute of Neurological Disorders and Stroke. Retrieved June 30, 2023, from https://www.ninds.nih.gov/health-information/disorders/traumatic-brain-injury-tbi