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Traumatic Brain Injury in Children

Introduction

An 8-year-old boy named Omar was a bright student, always excelling in school. One day, while he was heading home, he was involved in a car accident. The car rolled over the street, and the airbag inflated. He was not wearing his seatbelt, which left him hitting his head violently. He lost consciousness and was promptly transported to the hospital, where doctors diagnosed him with a traumatic brain injury (TBI). Although his physical wounds healed, the injury affected his memory, attention, and problem-solving skills. A few months later, when Omar returned to school, he felt left behind, and he realized things were different. His classmates were progressing while he felt stuck. He struggled academically, forgetting instructions, falling behind in math, and finding writing difficult. He could no longer remember how to solve problems he had mastered before the accident. Socially, Omar felt isolated, as his slower processing made it harder to keep up with conversations or group activities. Eventually, Omar discovered resilience and new ways to succeed despite the challenges of TBI. He showed progress with the support of his family, teachers, and speech and language pathologist (SLP).

TBI has been considered the leading cause of cognitive, academic, and social problems in children, with effects ranging from mild to severe. This paper investigates the types, causes, effects, and possible interventions for managing TBI in children.

Definition

"Pediatric Traumatic Brain Injury" defines traumatic brain injury (TBI) as a general term describing a variety of manifestations, ranging from mild to severe, that result from bumps, direct or indirect blows to the head, and other injuries affecting the brain's ability to function properly ("Pediatric Traumatic Brain Injury"). Classifying severity can help provide a better assessment and intervention. According to Cristofori and Levin, TBI severity is typically classified into three broad terms: mild, moderate, and severe. These categories are based on the degree and type of injury, the duration of loss of responsiveness, and post-traumatic amnesia (PTA), which refers to memory loss after the injury (Cristofori and Levin 580-581). First, mild TBI is characterized by a loss of responsiveness for less than half an hour and PTA lasting less than a day. It is divided into two types: uncomplicated and complicated. Uncomplicated mild TBI shows no obvious abnormalities in the brain, whereas complicated mild TBI shows noticeable problems in the brain. Second, moderate TBI is characterized by a loss of responsiveness and PTA lasting from one hour to twenty-four hours. Third, severe TBI involves a loss of responsiveness for twenty-four hours or more and PTA lasting more than a week ("Pediatric Traumatic Brain Injury").

Table:1 Classification of traumatic brain injury severity

	Mild	Moderate	Severe
Post-traumatic amnesia	< 24 hours	<24 hours >24 hours	≥7 days
Altered consciousness Structural neuroimaging	≥24 hours Normal	<7 days Normal or abnormal	>24 hours Normal or abnormal

Source: (Cristofori and Levin 582)

The table above categorizes TBIs as mild, moderate, or severe. Mild TBIs involve brief unconsciousness (less than 30 minutes), short-term memory loss (under 24 hours), and normal brain scans. Moderate TBIs show longer periods of unconsciousness (30 minutes to 24 hours) and memory loss (1–7 days), with brain scans that may reveal damage. Severe TBIs involve unconsciousness for over 24 hours, memory loss for more than 7 days, and likely brain abnormalities. This classification is essential for guiding treatment, predicting recovery outcomes, and understanding the potential impact on cognitive and functional abilities.

Classifications of TBI

According to Cristofori and Levin, TBI can be classified based on the physical mechanisms that cause brain damage, such as head acceleration, explosions, or external objects penetrating the brain. These mechanisms play a significant role in determining the long-term consequences of TBI. TBI is typically categorized into four types: closed, penetrating, concussion, and blast. The first type, closed TBI, occurs when rapid head movement injures the brain without breaking the skull. This can result in diffuse injuries, disrupting brain function across multiple domains. In contrast, penetrating TBI happens when an object pierces the skull and directly damages brain tissue, which can cause cognitive deficits depending on its location. Concussion TBI, the third classification, occurs due to a sudden jolt to the head that causes temporary dysfunction. Concussions are typically mild, with symptoms that generally resolve within a week. Finally, blast TBI is a type of injury that can occur without a direct blow to the head. It results from pressure changes caused by explosions (Cristofori and Levin 581). Understanding these classifications is essential for exploring the causes and effects of TBI.

Chronicity and Intentionality

As demonstrated by Cristofori and Levin, TBI can also be categorized based on the phases of recovery: acute, subacute, and chronic, which relate to the concept of chronicity and are defined by the duration of recovery. Acute TBI refers to the immediate period following the injury, while chronic TBI describes the long-term consequences and effects after the acute phase. Subacute TBI represents the period between the acute and chronic phases (Cristofori and Levin 581). The duration of each phase depends on the severity of the TBI. Table 2 shows the variation in recovery for mild and moderate-severe TBI. While recovery phases outline the timeline of effects, intentionality highlights how the nature of the injury impacts outcomes. Outcomes of TBI can be influenced by intentionality; children with non-intentional TBIs had better outcomes compared to those with intentional TBIs (Cristofori and Levin 593). According to Cristofori and Levin, "cognitive impairments were reported in 45% and 5% of the intentional and non-intentional TBI groups, respectively" (594).

Table 2: Definition of recovery phase of traumatic brain injury

Phase	Mild	Moderate-severe
Acute:	< 3 months;	Acute hospital care
Subacute:	>3 months < 6 months;	Inpatient rehabilitation
Chronic:	>6 months < 12 months;	Outpatient rehabilitation

(Cristofori and Levin 582)

The table illustrates recovery timelines for mild TBI: acute (0-3 months), subacute (3-6 months), and chronic (6-12 months). In contrast, moderate-severe TBI does not naturally recover within these phases without structured intervention. The acute phase requires acute hospital care, the subacute phase involves inpatient rehabilitation, and the chronic phase focuses on outpatient rehabilitation to support long-term recovery and quality of life.

Causes of TBI

The causes of TBI vary significantly across age groups due to developmental and behavioral differences. As indicated in "Pediatric Traumatic Brain Injury," for younger children, physical mechanisms such as falls are the leading cause of TBI, accounting for 50.2% of cases. This is followed by hit-by/against events, which account for 24.8%, and external objects striking the head are also major contributors to injuries. In contrast, adolescents are more likely to sustain TBIs from speed-related accidents, such as motor vehicle crashes or sports-related injuries ("Pediatric Traumatic Brain Injury").

Cristofori and Levin asserted that the risk of sustaining a TBI is highest during the ages of 0 to 5 years and 12 to 18 years. They explained that children in early childhood are in a critical phase of developing motor skills. Their limited coordination and balance make them more prone to accidents that lead to head injuries. On the other hand, the prefrontal cortex, responsible for impulse control and judgment, is still maturing during adolescence. This implies that adolescents are more likely to engage in behaviors that lack foresight or consider consequences. Cristofori and Levin stated, "The rate of TBI in early childhood is 1,256 per 100,000 cases and in adolescence is 757 per 100,000 cases" (Cristofori and Levin 583-593).

Cristofori and Levin also reported that closed TBI frequently occurs due to car accidents, falls, physical assaults, and sports-related incidents. In contrast, penetrating TBI, which occurs when an object breaks the skull, is more common in military contexts. Additionally, blast injuries, often associated with explosions, share characteristics with falls or car crashes. A concussion TBI is a mild form of TBI commonly linked to sports injuries (Cristofori and Levin 583-586).

Additionally, pediatric TBI can be caused by the acceleration of the head, as seen in Shaken Baby Syndrome (SBS) ("Pediatric Traumatic Brain Injury").

According to Chevignard et al., one specific type of TBI, Shaken Baby Syndrome (SBS), a type of Abusive Head Trauma (AHT), is another major cause of TBI in infants. SBS occurs when a baby is forcefully shaken, usually due to abusive actions. SBS mostly affects male infants, especially those under one year old, with most cases occurring before six months. The annual incidence is reported as 20–30 per 100,000 children. In severe cases, SBS has a higher mortality rate compared to accidental TBIs: "SBS can lead to sudden death". It can also result in long-term consequences that can include cognitive and physical impairments (Chevignard et al. 467-468).

Signs and Symptoms of TBI

According to Pediatric Traumatic Brain Injury, the signs and symptoms of TBI vary, and each case is different. Manifestations of TBI differ based on the injury's location, the severity of the brain deterioration, and the person’s age and previous skills. Additionally, the affected functional areas include language, sensory processing, cognition, and physical abilities. The consequences of TBI may be short-term or long-lasting, and every child displays a unique pattern. Furthermore, the effects of TBI in children can differ from those in adults due to the ongoing development of the pediatric brain. As a result, some children may not show immediate manifestations of TBI but will face difficulties later as their academic responsibilities grow. These difficulties have the potential to impact career achievements, social relationships, engagement in various settings, and overall well-being ("Pediatric Traumatic Brain Injury").

Manifestations associated with TBI include dizziness and fatigue, along with headaches and challenges with movement and balance coordination, known as vestibular dysfunction or muscular weakness, either partially or entirely. Furthermore, sensory and auditory disorders can result from injuries and affect different components of the auditory system, such as the outer ear, middle ear, and inner ear. These injuries may lead to a range of symptoms, such as disorientation, a spinning sensation, and imbalance, which are often associated with balance system disorders. Additionally, tinnitus, or ringing in the ears, and continuous hearing loss can also occur as a consequence of such damage. After an injury or dysfunction, the way you see things can change in terms of color perception and how you perceive shapes and sizes, along with judging distances and depths. Furthermore, some people may become more sensitive to light, a condition known as photophobia, which may make them feel uneasy in lit surroundings. These changes can make visual processing even harder to handle smoothly and efficiently in daily tasks and overall quality of life ("Pediatric Traumatic Brain Injury").

Cognition after a TBI can be significantly impaired, with attention being one of the most affected areas. One major issue is the difficulty in shifting attention between tasks, making it challenging for an individual to transition from one activity to another. Additionally, sustained attention is often impaired, making a person less able to engage with tasks or conversations over time. This often leads to a lessened attention span, further hindering one's ability to stay engaged and complete tasks effectively. These attention-related challenges can compound difficulties in executive functioning, which includes the cognitive processes required for planning, decision-making, problem-solving, and behavior regulation. When executive functions are compromised after a TBI, individuals may experience problems with selecting and adapting to new situations, setting and achieving goals, and initiating or self-regulating activities. Together, impairments in

both attention and executive functioning create substantial barriers to everyday functioning and independence. Memory is also impacted, which reduces the person's capability to receive new information. This can result in complications regarding any given instruction; the individual also has difficulty recalling information ("Pediatric Traumatic Brain Injury").

According to “Pediatric Traumatic Brain Injury,” another key point is the communication domains affected, such as language and speech. Individuals with TBI may exhibit problems in the social use of language, initiating and maintaining conversations, and catching social cues. Not only that, but they also struggle to produce smooth, well-spoken language. On top of that, they have trouble understanding written text, particularly when it includes complicated sentences. Sometimes, this difficulty with comprehension can extend to speech as well, as speech disorders manifest themselves in many ways, affecting various aspects of communication. Apraxia of speech, for example, involves a motor speech disorder where the brain has trouble coordinating the movements needed to produce speech correctly. This results in problematic articulation of words and challenges in sequencing sounds properly, further compounding the individual's communication difficulties ("Pediatric Traumatic Brain Injury").

Effects and Consequences

The brain develops and acquires most of its skills during childhood. As debated by Chevignard et al., children's brains are more flexible due to increased plasticity and growth compared to those of adults. When something goes wrong with the brain, it can affect several areas, including the development of cognitive and executive functions. These deficits are common after childhood TBI, impacting both cognitive functions and behaviors. This results in difficulties with daily

tasks like following instructions and taking notes. Social adaptation may also be affected, especially in noisy environments (Chevignard et al. 460-461).

Babikian et al. indicate that outcomes and consequences depend on factors such as severity, chronicity, and age (1849). Generally, the younger the individual and the more severe or chronic the injury, the more significant the outcomes. Chevignard et al. emphasize that TBI is the leading cause of mortality in children (452). Furthermore, Cristofori and Levin note that early childhood brain development is particularly vulnerable to lasting damage due to the physiological sensitivity of the brain; even minor injuries can result in serious TBIs (583).

As discussed by Babikian et al., studies show that the ages 7-9 represent a crucial period for brain development. During this time, the brain experiences significant growth and strengthening; injuries during this period can have the most severe impact on cognitive abilities, as the child with TBI may struggle to acquire skills and knowledge compared to peers, which can affect academic achievement. Additionally, students may face challenges in learning and experience problems forming relationships with peers due to behavioral issues (Babikian et al. 1849-1854).

Chevignard et al. highlight that learning deceleration occurs over time and affects reading, writing, and arithmetic, emphasizing the need for long-term follow-up (463). Additionally, children with TBI may encounter writing problems and difficulties participating in school activities due to motor deficits caused by the injury (456). A child with TBI might require repeated instructions during math lessons and still struggle to remember the steps, leading to delays and frustration. This can cause children to fall behind their peers academically (460).

Moreover, Chevignard et al. point out that processing speed is typically the most impaired ability and a key concern in clinical settings, significantly impacting daily life at home and school

(459). In addition to cognitive issues, as Babikian et al. highlight, children with TBI frequently deal with challenges in language and communication. They may struggle with social contexts, such as turn-taking, maintaining topics, and understanding humor or sarcasm, all of which can complicate social interactions (Babikian et al. 460).

As stated by Chevignard et al., children with severe TBI face limitations in community activities and social interaction. They report fewer strong relationships and engage less frequently with peers compared to typical children. Several years after the injury, many children with severe TBI are diagnosed with secondary attention deficit hyperactivity disorder (ADHD). This condition shares similar symptoms with ADHD but does not meet the full diagnostic criteria, which is why it is termed 'secondary.' It often leads to difficulties with listening and impaired executive function (Chevignard et al. 460-463).

Babikian et al. show that TBI has a lifelong impact on children’s lives, potentially persisting into adulthood and affecting workforce participation and overall quality of life (1849). Based on Chevignard et al., slow processing speed and difficulty with executive tasks may limit opportunities in high-demand professions (459).

Treatment

According to Pediatric Traumatic Brain Injury, before the start of the treatment process, a comprehensive assessment is required. It usually begins with the case history of the child's medical and social background; the next step is an interview with the child's caregiver in case any further information is required. Once this initial assessment is complete, treatment involves a multidisciplinary team that includes doctors, SLPs, occupational therapists, physical therapists, and, most importantly, the caregivers. Cooperation and collaboration are the keys to managing

speech and language pathology for children with TBI, encompassing multidisciplinary expertise and skill to understand functional abilities, extend support in a wide range of clinical areas, enhance outcomes, and facilitate the return to home, school, and community ("Pediatric Traumatic Brain Injury").

As stated in Traumatic Brain Injury in Children, when treating children, doctors focus on the child's overall health and assess important areas such as memory, vision, balance, and sensation, whereas occupational therapists (OTs) work on enabling children to regain necessary skills for daily living activities. Some areas OTs focus on include cognitive abilities and personal skills. On the other hand, physical therapists (PTs) focus on improving the child's strength, balance, and coordination. Some of the targeted skills for PT therapy include walking, sitting, standing, and running, which enable the child to move and perform tasks effectively. Moreover, SLPs work on the improvement of speech, listening, reading, writing, social interaction, memory, attention, and problem-solving skills ("Traumatic Brain Injury in Children").

As mentioned in Pediatric Traumatic Brain Injury, a variety of treatment methods can be used when intervening with children with TBI. First, restorative strategies include direct therapy, which focuses on the restoration of impaired functions by retraining. Therapy follows a hierarchical structure, first addressing specific challenges in one area, then progressing to more challenging tasks in that area. Finally, generalizing those skills to functional activities. At the same time, habilitative strategies focus on skills that the child has not yet developed. This type of method helps children learn, regain, or enhance their skills and functions after injury rather than regain those they previously had mastered. Compensatory strategies correct deficiencies by learning new or alternative ways of performing the activity that will minimize the difficulties.

These strategies make use of the child's strengths in developing his skills and frequency with the assistance of external and internal tools. Functional or contextualized strategies give relevance to significant personal goals, routines, and activities, ensuring that the acquired skills would be generalized and functional in social and educational environments. Another important role of such strategies is that they help ensure assistance and collaboration by teachers, parents, and classmates, enabling the child's family to generalize acquired skills to areas of importance for them ("Pediatric Traumatic Brain Injury").

Conclusion

TBI is recognized as the primary cause of cognitive, academic, and social difficulties in children, with effects varying from mild to severe. TBI can affect a child while playing, falling off the bed, or in a car accident; in turn, it may affect a child's memory, attention capabilities, and cognitive performance. The effects of TBI could range from temporary symptoms to long-term challenges related to learning, socializing, or engaging in daily activities. Children, mainly those aged under 5 years and teens, are at a higher risk. Treatment is a team affair wherein doctors, therapists, teachers, and caregivers work with the child toward regaining or adapting his skills. Despite the challenges, a team-based approach provides hope for children with TBI to regain abilities and improve their quality of life. Like Omar, many children with TBI can regain abilities and find new ways to succeed with proper support.

Recommendations

Recommendations for Preventing TBI in Children:

- Safety Education: Parents should teach children about safety rules, such as the necessity of wearing seatbelts and helmets.

- Proper Equipment: Parents should let children wear proper, well-fitting protective sports equipment.
- Safe Environment: Parents should install safety gates at stairs and window guards to prevent falls in younger children.
- Promote Supervised Play: Parents should supervise younger children during activities like climbing or jumping and provide safety briefings for older children.
- Symptom Awareness: Symptoms associated with TBI include drowsiness, irritability, confusion, and disorientation. Parents should seek emergency care immediately if their child exhibits any of these symptoms.

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