Challenges in Children

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4.1 Incidence and Global Perspectives

Severe TBI in children and adolescents is a complex disorder, with large heterogeneity in both pathology and mechanisms. The impact of severe TBI is enormous as it is the leading cause of death and life-long disability in children and causes significant societal costs and consequences (Murphy and Duhaime 2012; Maas et al. 2017; Hawley et al. 2002).

The real incidence of paediatric TBI injury is difficult to assess due to the lack of definitive classification and lack of reliable data. The incidence numbers also seem to vary between publications, reflecting the difficulty in extracting data out of different hospital systems and regional differences in data collection. Usually the annual incidence rates in the paediatric population for European countries are in the range of 180–300 per 100,000 population. These rates include all severities. The majority (80–90%) of these are mild and approximately 10% is believed to be moderate to severe TBI (Astrand et al. 2016). In developing countries, the incidence of TBI is increasing, probably due to increasing use of motor vehicles. According to the WHO, TBI is expected to surpass many other diseases as a major cause of disability and death by 2020 (Murphy and Duhaime 2012). Boys are generally at a higher risk for TBI. Among children younger than 3 years, the gender distribution is split evenly, but with increasing age, boys have nearly twice the injury rate of girls (Faul and Coronado 2015). Data on the impact of ethnicity and socioeconomic status is generally lacking (Dewan et al. 2016).

4.2 Age Distribution and Mechanisms

Activities and thus vulnerabilities vary greatly within the paediatric population, which is reflected in the mechanisms of injury. Incidences vary with age and societal factors. The majority of TBIs among infants and young children are due to falls, while adolescents are mostly injured during sports, recreational activities, and motor

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vehicle accidents (MVAs). In the age group between these two (5–14 years), falls are as common as collisions (Maas et al. 2017; Trefan et al. 2016). The highest incidence of TBI registered in the paediatric population is among infants and young children (0–4 years old). The second peak of incidence is reported among adolescents.

Most paediatric TBI injuries are due to MVAs (6–80%) and falls (5–87%). Abuse and other forms of non-accidental trauma represent 2–12%, and sports-related injury <1–29%. As can be seen from the wide ranges, regional and cultural differences are great. Among sports, soccer, cycling, and horseback riding are most commonly associated with paediatric TBI in Europe. In Africa, Asia, and India more than half of the MVAs in the paediatric population involved pedestrians, while in China 43% of MVAs involved a bicycle. In Australia, Europe, and the United States, however, the MVAs typically involve vehicle occupants. Falls seem to be a more frequent cause of paediatric TBI in Asian populations than in western countries. Sports-related paediatric TBI was more common in Australia and the United States (2–29%) than in Asian countries (0.7–2%) (Dewan et al. 2016; Davies et al. 2015).

4.3 Child Abuse

The incidence of child abuse or non-accidental trauma (NAT) is difficult to determine. Reported data varies widely between countries. Published data indicate an incidence of 2–12% of TBI in children, and NAT is the most common cause of severe paediatric TBI in infants and small children (Dewan et al. 2016; Davies et al. 2015). A newly published Scandinavian study on the epidemiology of subdural haemorrhage (SDH) during infancy shows an incidence of 2.3 per 100,000 infants for abusive SDH in the Swedish population (Högberg et al. 2018). NAT is often very difficult to distinguish from accidental injuries. The clinical presentation may range from normal neurological findings to unstable vital signs and coma. Often no external signs of injury are present. As the victims typically are either too young or too injured to report the assault, the clinical challenge is profound.

The term "shaken baby syndrome" was introduced in the 1970s, indicating the triad of encephalopathy (irritability, vomiting, altered level of consciousness), SDHs, and retinal bleedings. It has been considered to indicate a mechanism of violent shaking of the infant. However, some reports have shown that the presence of this triad is not exclusively associated with abusive head injury (Swedish Agency for Health Technology Assessment and Assessment of Social Services (SBU) 2016). The outcome of abusive head injuries has the worst prognosis among all forms of paediatric TBI. Mortality rates range from 13 to 23%. Approximately 55% suffer from neurological deficits, among which visual impairments are common (Keenan et al. 2004).

4.4 Prevention

At best modern trauma care prevents secondary injuries, but preventive measures are absolutely needed to diminish the burden of TBI. Many causes of paediatric TBI are preventable and have obvious remedies, which need to be implemented effectively. For instance, the introduction of a road safety program in Brazil, China, Kenya, Mexico, Turkey, and Vietnam is estimated to have a profound effect, resulting in 109,000 lives saved during 2014–2023. The program includes legislation on drunk driving, motorcycle helmets, safety belt use, and use of fines to improve adherence to traffic regulations. Albeit with a great variability between countries, reduced drunk driving was the single most important factor (84%) in reducing lives lost (Miller et al. 2018). While it is obvious that reduced numbers of MVAs will result in reduced numbers of severe TBI (Chen et al. 2018), data also suggests that helmet use during biking in children reduces the risk of hospital stay and head and neck injuries (McAdams et al. 2018) and that this translates into reductions in severe TBI and trauma deaths (Socialstyrelsen 2017). This holds true also for sports-related TBI, where

helmet use in biking and horseback riding translates into reduced frequencies of trauma-induced amnesia, unconsciousness, and epidural hematomas (Bandte et al. 2018).

4.5 Features of Paediatric TBI

The peripheral and central nervous system in children differs from adults both in its anatomy and physiology; as a direct consequence, TBI in paediatric population shows some specific features and challenges. Anatomically the proportions between head and body differ between children and adults and vary during childhood. In newborns and infants, the head is large and heavy in respect to the rest of the body, and it will take several years to reach adult proportions. The brain of a newborn is around 25% of the size of an adult brain, while the total body weight is only 5% on average of that of an adult (Figaji 2017). Moreover, the heavy head is supported by weak neck muscles and stretchy ligaments that make it easier for both head and spine to get injured after a fall or other traumatic events (Hickman et al. 2015).

The skull and the cervical region reach different maturity stages at different ages. The posterior fontanel is the first to close around 2 months after birth while the anterior fontanel may stay open until 18 months of age. Even sutures close at different times, and this, together with fontanel, allows some adaptive margins when the intracranial volume increases. However, the level of volume increase is limited and does not adapt in case of quickly expanding volumes. Moreover, children have a lower intracranial pressure (ICP) than adults and tolerate only limited changes in ICP (Figaji 2017). (More details on ICP physiology, monitoring and treatment will be discussed elsewhere in this book.)

The skull in young children is thinner and more easily bendable than in adults. The skull may be easily deformed affecting the underlying parenchyma, even without any visible fractures. Typical fractures in infants and young children are for instance "ping-pong" fractures that will often remodel spontaneously; linear fractures may develop into "growing fractures", where the underlying dural tear will result in herniation of the brain. On the other hand, if the dura is intact, small skull fractures will heal completely thanks to the high osteogenic capacity of children's bones (Singh et al. 2016).

Special considerations should be taken for the vulnerability of the parenchyma of the developing brain. At birth the axons lack their protective myelin sheet, and it will take several years before the myelinisation process will be completed. It has been shown that unmyelinated axons are more vulnerable to injury leaving the young child brain more easily subjected to diffuse injury patterns (Babikian et al. 2015).

In this chapter, we have presented only some aspects that characterize and differ paediatric TBI from TBI in adults. The anatomical and physiological differences are clear; however, we are still lacking paediatric-specific data and guidelines. There are only few studies available, and at the moment, there is not enough evidence to support clinical recommendations. More paediatric-specific studies are needed.

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