HEAD INJURY IN CHILDREN

Josip Mihić[1], Krešimir Rotim[2], Marcel Marcikić[1] and Danko Smiljanić[1]

[1]Department of Surgery, Dr Josip Benčević General Hospital, Slavonski Brod; [2]University Department of Neurosurgery, Sestre milosrdnice University Hospital Center, Zagreb, Croatia

SUMMARY – Nowadays, head injuries are becoming more frequent in children. The most common cause of head injuries in children is fall, and, in more severe injuries, traffic accident trauma. In traumatic brain injuries in infants and small children, the most common symptoms are paleness, somnolence and vomiting, the so called "pediatric contusion syndrome". After the first year of age, light head trauma occurs after minor falls, whereas the most severe injuries are caused by car accidents, including pedestrians, or fall from the height. As the child grows, severe head trauma is more likely to occur after bicycle or car accidents. Brain injuries involving or penetrating the brain by broken bone fragments include contusions and lacerations of the brain. Unconsciousness need not always occur during contusion, as it may also appear after swelling of the brain or high intracranial pressure complications. Despite comprehensive injuries in such types of accidents, the outcome of survivors is surprisingly good. Such severe neurocranium injuries usually include heavy bleeding with hematoma (epidural bleeding, subdural bleeding, intracerebral bleeding, and traumatic subarachnoid hemorrhage). Improved prehospital care, readiness and accessibility of multidisciplinary teams, establishment of regional centers, and efforts to prevent and decrease traffic accidents contribute to mortality rate reduction.

Key words: *Craniocerebral trauma; Child; Neurosurgery; Head injury*

Introduction

According to the literature, trauma is the most common cause of death in children[1]. In the USA, 300,000 to 400,000 children are hospitalized for traumatic brain injuries (TBI) every year, or 230/100,000 *per* year, and even more are medically treated (12,000/100,000 *per* year)[1,2]. Available data reveal that such trauma causes death in 6000 to 7000 children younger than 14[2].

The most common cause of head trauma in children is fall, while more severe head injuries are connected with traffic accidents. Contemporary way of living in urban as well as rural settings contributes to neurocranium trauma. It can be seen that certain types of injury are related to the child's age and development. Thus, the most common causes of head trauma in the first year of age are falls from parental arms, from changing tables or chairs, and are usually low-impact injuries. As the child learns to walk, falls from greater heights occur. As the child grows, due to the lack of research abilities, accidents of the car-pedestrian type are becoming more common. Nowadays, we are witnessing fights among children that sometimes result in death. In older children, there is an increasing prevalence of bicycle accidents, sports injuries, car accidents with the child as a passenger in a motor-car, and suicide accidents[1].

Correspondence to: *Josip Mihić, MD, MS,* Department of Surgery, Dr Josip Benčević General Hospital, Andrije Štampara 42, HR-35000 Slavonski Brod, Croatia
E-mail: j_mihic@yahoo.com

Received April 1, 2011, accepted June 1, 2011

Injuries in the First Two Years of Age

The most common cause of head injury in the first two years of age is fall. These falls are usually from small heights, often onto a soft surface, and are rarely combined with consciousness disorders or intracranial injury. Studies have undoubtedly shown that smaller falls, and even bigger ones, do not cause intracranial trauma, although cranium fractures are rather common[3-5].

In children under two years of age, epidural hematoma is usually seen after accidental trauma. At the same time, fall off the stairs or from a walker, as well as fall of an adult onto the child is reported. It should be noted that acute subdural hematoma is possible in this age group only in cases of great velocity impact, as in car accidents or in child abuse, whether due to direct impact or as an injury caused by child shaking. When a heavy brain injury, subdural hematoma or retinal hemorrhage is alleged to be the result of a minor or unnoticed trauma, the story is almost always false, and the etiology is premeditated trauma (a child injury caused by other person or parent). Light child injuries are rarely the cause of severe brain trauma[1].

The most remarkable symptoms and signs of neurocranium injuries in infants and small children are paleness, somnolence and vomiting, the so called "pediatric contusion syndrome"[6]. This kind of development is noted in 10% of head trauma admissions in children, and is supposedly occurring in a larger number of cases as a mild form of the commotion syndrome. It can be deferred for a few hours to several days after injury and can imitate an intracranial mass. Vomiting can be so severe to demand intravenous fluid administration. Generally, soft fontanelle is noticed, while intracranial masses are rare. If the fontanelle is tense, and standard radiographic scans show divided structures or/and the vomiting continues or low rates of blood hematocrit are found, computed tomography (CT) of the brain is needed. It is a temporary syndrome, so parents should be convinced that it would pass without any residual neurologic problems.

It is significant that the common causes of severe head trauma are accidents in which the child is a car passenger, either in the child seat or not bound with the belt. Thereby, unbound children may fly over the cabin as a projectile and are often found underneath the seat or the car dashboard, usually apneic. The cause of fatal injury usually is spinal cord lesion, followed by apnea and cerebral ischemia[1].

Injuries in Older Children

After the first year of age, the largest number of light head injuries result from smaller falls, whereas most severe injuries are the result of accidents involving the car and the pedestrian, and falls from great height[1]. As the child grows, more severe head trauma is much more common after bicycle or car accidents. Thus, from the infant age to the age of ten, the most important causes of serious head injuries are not impacts, but acceleration-deceleration forces. Between the age 10 and 15, the prevalence of impact caused trauma is increasing (for example, bicycle falls or sports injuries). The consequences of impact caused trauma are mostly local, unless the mass accumulation shows, followed by intracranial pressure increase and cerebral herniation. On the other hand, injuries caused by acceleration-deceleration forces are almost always diffuse.

Clinical Characteristics of Injuries

In children and adolescents, it is necessary to get detailed case history that will illuminate which type of injury we are dealing with, the height from which the child has fallen, the characteristics of the floor (covered with carpet or not), the initial state of consciousness (crying child or not), the onset and the occurrence of apnea. It is vital to identify the course of events: Has the child's state improved, stabilized or worsened? Has there been any vomiting? Have the late convulsive attacks appeared? Whenever case history does not adequately explain neurologic signs, it can indicate abuse[1].

The Glasgow Coma Scale (GCS) grading system is administered for consciousness stage quantification[1,7]. It is a useful tool that should be used in careful and precise manner. Few studies have shown good correlation between GCS stage and neurologic outcome[8-10].

In a child younger than 2, the GCS system can be used, however, with some limitations, which is important for initial coma stage evaluation. In the first few months, neurologic examination includes palpation of the fontanelles and sutures, examination of postural tonus changes or clonus, and testing for the presence of primitive reflexes (for example, Moro reflex). After brain concussion, vegetative symptoms are exceptionally common, including paleness, vomiting and tachycardia. It is important to monitor the state of consciousness, breathing spontaneity, pressure and heart rate, if needed, eye funduscopy, etc. Hypotension is rarely the consequence of head trauma and it should be assumed to occur due to the loss of blood somewhere in the body (for example, abdomen) or because of long bone fracture or in linear neurocranium fracture in children under one. Hypotension can also appear after spinal cord injury.

Treatment of Children with Neurocranium Injuries in Hospital Practice

Traumatic brain injury is the most common cause of death and acquired inability in childhood and younger adult age in developed countries, so that there is neurologic deficit even if appropriate medical care is administered[11]. It can also be said that among all fatal child injuries, brain trauma is by far most numerous[12]. The pathophysiology of this state emphasizes the importance of not only primary lesions, but also of secondary processes that can lead to cerebral hypoxia and ischemia. Secondary brain damage is the leading cause of death in hospital after TBI. Furthermore, head trauma outcome in childhood varies between the centers, depending on the availability of modern neurosurgical and neuroradiological facilities, qualified personnel and specific patient monitoring options (jugular vein saturation, intracranial pressure monitoring and transcranial Doppler sonography).

Some researchers have concluded that age is a good death predictor in TBI[5]. Younger people have a higher survival probability, they tolerate longer period of coma or decerebration in relation to adults, and have fewer life threatening complications. Radiologic CT scans reflect the severity and predict clinical course of head injuries. The specificity of children physiology and decreased capacity of tolerating intracranial noxae, according to smaller body mass and volume in relation to adult patient surely reduces the time frame for development of secondary brain damage[13]. Although it is known that children generally have better recovery capacity for the same type of brain injury comparing to adult patients, it has been noticed that children under age 4 have a smaller chance for full recovery than older children.

Clinical researches have confirmed far better results in the treatment of children in specialized centers[14-19]. Literature states that it is hard to operate a pediatric patient with intracranial hematoma within 4 hours from injury in practice[20]. This time interval of 4 hours from accident until neurosurgical procedure in a patient with compressive intracranial hematomas is often mentioned in literature and is compatible with neurosurgical practical experience. In fact, it has been shown that patients in which the operative neurosurgical procedure has been conducted in 3 to 4 hours from injury have a better treatment outcome. This time limit for the procedure and the speed of hematoma filling that pressures the brain directly affect the need of undertaking operative treatment as soon as possible and are a predictor of treatment outcome. Thus, such neurosurgical procedures should be performed as soon as possible. On the other hand, in slowly growing hematomas, treatment outcome is equally good if it is conducted in a period longer than 4 hours from the accident. Unfortunately, no test except for clinical picture can predict the speed of hematoma filling.

In developing countries, the incidence of accidents is multiplying with traffic increase and other factors, such as falls, industrialization, ballistic trauma, etc. Head injuries are the cause of a quarter to one-third of all deaths in various types of accidents and two-thirds of deaths in hospitals, also as the result of different forms of accidents[21,22].

Analysis of children injuries in the USA has shown that TBI in children (age 0-19) causes up to 7000 deaths, 60,000 hospitalizations, and more than 500,000 emergency visits *per* year[23,24]. Childhood TBI contributes greatly to the economic health burden, with estimated 1 billion dollars of hospital costs *per* year[23].

Analysis of neurocranium injuries reveals that only a few authors have investigated such pediatric traumas, although they are common in childhood. In a recent study, Yattoo *et al.* from India investigated TBI in different age groups (including children) and showed the age of the injured to range from 6 months to 80 years; however, most (25.5%) of these injuries were recorded in the youngest, 0-10 age group[21]. This is consistent with data reported from other studies, where the highest incidence of head trauma was found in the 2-10 age group[25]. According to the Accident and

Emergency Department data, the maximum is observed at age 10[22]. Similar data have been reported by Kennedy *et al*. from their study including 192 injured patients, of which the majority (90%) were in the 0-14 age group[26]. On the other hand, data on the mortality rates and head trauma in Great Britain show the highest incidence in the 15-30 age group[26-28]. According to Yattoo *et al*., the highest incidence is recorded in the 0-10 age group (25.5%), followed by the 21-30 age group (21.2%), then the fourth (18.2%) and second (15.5%) decade of life[21]. It is assumed that this active society group (21-30) spend most of the time outside home for education and work, thus being more prone to accidents[21].

The main question is the type of infliction and form of injuries of neurocranium in children. In unintentional pediatric neurotrauma, the category of head injury caused by contusion is especially common[27]. These are static injuries that are caused by force working longer than 200 ms. In such injuries, head is static (or is in static position at least in the beginning of the injury), and strong forces harm the head with possible fractures of facial bones, calvary and base of the skull. An example of contusion injury is fall of a heavy object onto the head. Brain injuries that occur upon contusion of the head are contusions and lacerations of the brain, most commonly caused by fragments of fractured bones that harm and penetrate the brain. In these cases, there are no coup-contrecoup injuries, but contusions and lacerations that are related to fractured fragments of bones should be marked as fracture contusions, so that the mechanism of their occurrence can be identified. When contusion occurs, it may not be associated with unconsciousness episode, but it may occur upon development of brain edema and complications entailed by increased intracranial pressure. Despite extensive injuries in this type of accidents, several studies have shown that some children survive these massive injuries and that the outcome of the survivors is amazingly good[28,29].

In their study of 547 TBI patients (including children), Yattoo *et al*. found traffic accidents to be the main causes of head injury, followed by fall from the height[21]. It is important to note that minor falls (from smaller heights) are a common cause of pediatric neurocranium trauma. It is a common phenomenon in children because probably every child experiences one or more falls, from infancy throughout childhood[27]. Fortunately, most of these falls in childhood do not lead to severe trauma. When examining an injured child, physicians sometimes face a dilemma whether such head injuries in children are really the consequence of a fall (as reported by the parent or guardian through heterohistory), or of deliberately inflicted injuries. Light falls that happen in or around the house from heights shorter than 3 meters primarily lead to focal contact injuries such as lacerations of the scalp or contusions, although in most of the patients there are no signs of injury[27,30-32]. Around 1% to 3% of light falls in younger children cause skull fractures that are mostly simple linear fractures without any intracranial bleeding or neurologic deficit involved. Less than 1% of these fractures cause epidural bleeding, and even less subdural hemorrhage. Considering that skull fracture can be found at the site of outer bone curvature, fracture and bleeding can develop at the site distant from the site of impact. In light falls, even in those with skull fracture, the period in which energy transmission to the head occurs is so short that it leads to minor deformities of brain tissue at the sites far from the point of impact, and not to diffuse brain injury. Although there can be a contact focal injury in the form of skull fracture or fracture brain contusion, a group of authors consider that there is no possibility of traumatic diffuse axonal injury[3,27,30-32]. An opposite opinion is found in the study by Ommaya *et al*., stating that, in a younger child, it is precisely the contact injury that can spread to the brain[33].

On the other hand, neurocranium injuries can occur after fall from greater heights and are the main cause of unforced trauma and mortality, especially in urban populations where children are at a greater risk of falls from buildings, walls, stairs, etc.[27]. In a study in which children were monitored after falls from greater heights (61 children younger than 16), it was confirmed that all children who fell from the third or lower floor had survived, whereas in those that fell from the fifth or sixth floor the mortality rate was 50%[34]. It has been shown that 23% of the children died, with fatal head trauma as the most common cause of death (78%). The most common injuries included skull fractures and brain contusions identical to those occurring in contusion head trauma. Another study monitoring 70 children (aged 10 months to 15 years), admitted to the hospital after falls from heights greater than 5 meters to 17 floors showed that all of them survived the injuries sustained; 50% were younger than 3 years and most of the falls were from the first to the third floor[35]. In the study by Case, the most common injury was head trauma, recorded in 54% of cases, including skull fractures and intracranial bleeding[27].

Severe injuries of neurocranium are still less common in childhood [heavy bleeding with hematoma (epidural bleeding, subdural bleeding, intracerebral bleeding, traumatic (SAH)]. According to Case's results, epidural bleeding is generally found in around 3% of all head injuries with the highest incidence in the 10-30 age group[27]. Such bleeding is not common in the first two years and after 60 years of age because the dura is tightly connected to the inner side of the skull[36,37]. On the other hand, Hahn *et al*. analyzed 738 head injuries in children younger than 16 and found a history of epidural bleeding in 44% of intracranial bleeding cases, 75% of these in children younger than 3 years[38].

According to Rivas *et al*., epidural bleeding was associated with skull fracture in about 85% of cases (general population)[39]. Bleeding mostly occurs from lacerations of medium meningeal artery branches after movement of fractured bone fragments, after which blood pressure separates dura from the inner side of the skull. Skull fractures can cause lacerations of small medium meningeal artery branches because they lie in grooves on the inner side of the skull. Impact to the head can lead to skull deformities without causing fractures, since the deformity can be sufficient to separate dura from the inner surface of the skull causing lesions to small blood vessels. Grooves in which these blood vessels lie do not develop until 4 years of age, when diploë growth occurs[40]. In some cases, epidural bleeding develops from torn dural sinuses or diploic veins, but not arteries. Based on the rate of hematoma growth, it can be estimated whether it is venous or arterial bleeding[27].

Epidural bleeding is a contact injury and requires an impact to the head. Small children usually suffer from epidural bleeding after experiencing a fall. Much less commonly it is caused by an impact to the head, which will cause acceleration of the head and diffuse brain injuries. Nevertheless, epidural bleeding may be caused by impacting the head that is static. This occurs most commonly at cerebral convexities, in parietal and temporal regions, although it can be found in the frontal and occipital region, as well as in the posterior pit. Bleeding in the posterior fossa is mostly of venous origin, so that small amounts of blood can signify massive lesions[27].

Subdural bleeding occurs between hard membrane and brain hemisphere. Unfortunate circumstances that could cause inertial acceleration-deceleration forces that impact the head of the child have been studied as a possible cause of inertial subdural bleeding in younger children[27,41]. Contact mechanism can also produce subdural bleeding. Of 1%-3% of falls from smaller heights that led to skull fractures, only a small number of cases were followed by contact subdural bleeding. These cases are the result of skull deformities and subdural bleeding is localized at the contact site[27].

Contusions of the brain can often be seen with skull fractures, so these contusions should be noted as fracture contusions. Coup-contrecoup contusions do not or only rarely occur in children under 4 years of age. There are several reasons for which such contusions do not take place. When strong forces affect the head, soft consistency of a young brain makes it less prone to contusions than lacerations. On rare occasions, coup contusions can appear in smaller children, but are imposing more as light redness on cortex surface than as fully developed hemorrhagic contusion. Sections of these reddish contusions discover smaller hemorrhagic components inside the cortical lamina. There is a light or no SAH included. Contrecoup contusions occur when head movement accelerates by fall from standing position, making a spin force that impacts the body and then the head falls on a hard surface[42]. A small child does not fall as a rigid body falls. It is already near to the surface when it starts falling and its fall does not lead to head acceleration. After approximately the fourth year of age, children fall from standing position and develop a typical contrecoup contusion[27].

Several articles have been written about the incidence of falls in that age. Studies of lighter falls give information about subsequent injuries. Mostly, it is a case of smaller contact injuries such as hematoma and laceration. In 2% to 3% of falls, a simple linear skull fracture mostly does not result in neurologic deficit or intracranial bleeding. In about 1% of fractures, epidural or subdural bleeding occurs. Although these are relatively rare injuries, it is crucial to establish the mechanism of injury so that incorrect diagnosis would not be made[27].

Analysis of deadly injured children shows the seriousness of TBI and marks asphyxia as dominant (58%), followed by head injury (16%), and other causes[27].

Head injuries, except after falls or different types of impact, often occur in traffic accidents in which motor vehicles and motorcycles participate, in accidents where a vehicle rushes into a pedestrian, and other[21]. Motorcycle accidents are especially contributing to a significant rise of child TBI hospitalization, primarily amongst male teenagers between 15 and 19 years of age[23]. An increase in hospitalization rates has also been noticed as a consequence of traffic TBI in more than 65% of cases, with an especially significant rise in hospitalizations of children aged 5 to 19. It seems that during this period, the number of hospitalizations for bicycle and pedestrian TBI has decreased, as well as of those caused by using firearms, with minimal changes in the number of hospitalizations due to traffic accidents involving motor vehicles and falls[23]. During the 1990s, a great decrease was recorded in children hospitalization rates because of mild TBI, and that number has stabilized at a certain level of hospitalizations in the last few years[23,43,44]. Thurman and Guerrero monitored all age groups during the 1980-1995 period and found a decreasing trend in the number of hospitalizations for mild TBI because of tightened hospital admission criteria[44]. From 1989 to 1998, the mortality from TBI also decreased in the group of children aged 0-19[45]. The decrease in mortality rates can partially be connected to success in injury prevention, improvement in care provided before and during hospital stay, and development of the system of injury management in hospitals[23,46].

It has been spotted that enhancement of preventive measures for traffic safety (car safety, increased usage of children safety belts and child chairs, better roads) has reduced the rate of deadly outcomes at the site of the accident. Reduction in the rate of hospitalization of children hurt in bicycle accidents is supported by the measures of obligatory wearing safety helmets in children.

Several studies from different parts of the world show continuous increase in the incidence of head trauma[21]. One of 12 deaths in the USA is the result of TBI, with 147,505 injury associated deaths in 1994. There are studies from other parts of the world, e.g., mortality from TBI in Kashmir was on constant increase from 1996 to 2003, except for 1999, when a decrease in mortality was recorded[21]. Therefore, the greatest mortality from TBI was in the 21-30 age group (18.8%), followed by the 11-20 (17.8%) and 31-40 (14.3%) age group[21].

Few researchers have found age to represent a good mortality predictor in TBI[8]. Younger people have been found to have a higher probability of survival, to endure longer periods of coma, and to have less life-threatening complications in comparison with older people[8,9]. Nevertheless, according to some studies, the influence of age on severe head injury outcome in children is controversial[9,47-49].

The number of children injured in traffic accidents is linked to the number of motor vehicles on the road, which has drastically risen in the last decade. It appears that the increased utilization of safety belts and helmets, encouraged through various campaigns, would reduce the rates of severe head trauma[11,50].

In developing countries, traffic induced trauma is disproportionally more common and causes 85% of all deaths and 90% of disabilities[51]. In Latin American countries, traffic accidents are the sixth main cause of death and the third main cause of morbidity in all ages[52]. While developed regions have significantly reduced traffic accidents with well designed actions, successful interventions and legal priorities, many developing countries have an increase in traffic injuries rates[53].

Donroe *et al.* assessed personal and environmental risk factors for pedestrian injuries in San Juan de Miraflores in Lima, Peru[50]. They showed the higher risk of traffic accidents in pediatric pedestrian population to be influenced by several factors including great vehicle volume, lack of horizontal signalization, high vehicle velocity, great number of street sellers and a greater number of children living in the same household. Protective factors include more hours/days spent in school and more years spent with the family in the same home. It was shown that the reduction of traffic volume and speed, limitation of street sellers (characteristic of some developing countries, among them Peru) at certain parts, as well as improvement of horizontal signalization could be useful intervention measures[50].

It is important to influence the risk factors in preventing pediatric injuries due to traffic, including improvement of personal (education) and environmental risk factors (traffic pacifying)[54-56]. Literature mentions age, sex, household, overcrowding, poverty, single parent homes, and low level of parent or guardian education as personal risk factors for children injuries. Environmental risk factors include great traffic volume, high vehicle velocity, no walkways, and density of vehicles parked by the curb[50,56-61]. Most of these studies were conducted in developed countries, so the initiation and intervention strategies for developing countries relied on the results obtained in developed countries[45,62]. Extrapolating the practice of effective prevention measures from industrialized world to developing countries is often inappropriate. Measures can be too expensive and require complex technology, and also may exclude the risk factors that are specific for developing countries[55,63,64].

Donroe *et al.* demonstrated an exceptional relation of pediatric pedestrian traffic injuries with greater vehicle velocity, corresponding to other studies from developed countries[56,57,59]. It was shown that the risk of child injury could be similar on the roads with average vehicle speed of 25 km/h and 35 km/h, and the same risk increases when average vehicle speed reaches 45 km/h and more. The absence of horizontal signalization is probably contributing to disorganized vehicle flow, which probably leads to unpredictable traffic motions and complicates the child's assessment of when it is safe enough to cross the street. These two factors are especially common in developing countries and should be considered when designing the interventions for traffic injuries in childhood in these countries[50]. The results show that pediatric neurocranium injuries are mostly head lacerations, while more severe injuries with serious consequences are less common. It is evident that prompt recognition of intracranial bleeding and skull fractures improves treatment outcome of these patients owing to earlier surgical intervention.

According to current data (2011), approximately 1.7 million people suffer TBI annually with 52,000 deaths in the USA[65]. Although most of these injuries are mild (resulting in short-term disruption), many are severe and occasionally lead to permanent disability or death. Recovery is often slow and can appear even years after the initial injury[65]. TBI is estimated to incur direct and indirect annual costs of 60 billion dollars to the society. Therefore, effective treatment for TBI patients is essential to minimize these costs[65].

Conclusion

Considering that TBI is the most common cause of death and acquired disability amongst children and adolescents in developed countries, it is necessary to act on the prevention of the possible severe consequences. The prognosis of a child with head trauma cannot be estimated on the road. Improved prehospital care, readiness and availability of multidisciplinary emergency teams, establishment of regional centers, and attempts to prevent and reduce the number of motor accidents should improve the prognosis of severe head trauma in children. It is concluded that several factors should be highlighted as significant for TBI in children. TBI outcome depends on the regional economic status, whereby regions with higher incomes can enable better care. Strict compliance to the recommendations and guidelines for TBI care are associated with better outcomes and are more often found in high income regions.

References

1. BRUCE DA. Pediatric head injury. In: WILKINS RH, RENGACHARY, SS, editors. Neurosurgery, 2nd edition. New York, St. Louis, San Francisco: McGraw-Hill, Health Professions Division, 1996;2079-714.
2. ANNEGERS JF. The epidemiology of head trauma in children. In: SHAPIRO K, editor. Pediatric head trauma. Mount Kisco, NY: Futura Publishing Co., 1983;1-10.
3. CHADWICK DL, CHIN S, SALERNO C, *et al.* Deaths from falls in children: how far is fatal? J Trauma 1991;31:1353-5.
4. DUHAIME AC, ALARIO AJ, LEWANDER WJ, *et al.* Head injury in very young children: mechanisms, injury types, and ophthalmologic findings in 100 hospitalized patients younger than 2 years of age. Pediatrics 1992;90:179-85.
5. LUERSSEN TG, HUANG JC, McLONE DG, *et al.* Retinal hemorrhages, seizures and intracranial hemorrhages: re-

lationships and outcome in children suffering traumatic brain injury. Concepts Pediatr Neurosurg 1991;11:87-94.

6. VITZTHUM HE, WILLENBERG E, LAMPE J, MINDA R. Delayed encephalopathy. Zentralbl Neurochir 1986;47:131-3.
7. SIMPSON D, REILLY P. Pediatric coma scale. Lancet 1982:2:450.
8. LUERSSEN TG, KLAUBER MR, MARSHALL LF, *et al*. Outcome from head injury related to patient's age. A longitudinal prospective study of adult and pediatric head injury. J Neurosurg 1988;68:409-16.
9. TILFORD JM, SIMPSON PM, YEH TS, *et al*. Variation in therapy and outcome for pediatric head trauma patients. Crit Care Med 2001;29:1056-61.
10. WHITE JR, FARUKHI Z, BULL C, *et al*. Predictors of outcome in severely head-injured children. Crit Care Med 2001;29:534-40.
11. BAHLOUL M, HAMIDA CB, CHELLY H, *et al*. Severe head injury among children: prognostic factors and outcome. J Care Injured 2008:12:1-9.
12. GJURAŠIN M, ŠKARIĆ I, POPOVIĆ Lj, ŽUPANČIĆ B. Uloga pravodobnog transporta u liječenju djece sa teškom kraniocerebralnom ozljedom. Lijec Vjesn 2007;129:128-31.
13. GIZA CC, MINK RB, MADIKIANS A. Pediatric trauma brain injury: not just little adults. Curr Opin Crit Care 2007;13:143-52.
14. NOPPENS R, BRAMBRINK AM. Traumatic brain injury in children – clinical implications. Exp Toxicol Pathol 2004;56:113-25.
15. POTOKA DA, SCHALL LC, FORD HR. Improved functional outcome for severely injured children treated at pediatric trauma centers. J Trauma 2001;51:824-34.
16. POTOKA DA, SCHALL LC, GARDNER MJ, STAFFORD PW, PEITZMANN AB, FORD HR. Impact of pediatric trauma centers on mortality in a statewide system. J Trauma 2000;49:237-45.
17. HALL JR, REYES HM, MELLER JL, LOEFF DS, DEMBEK R. The outcome of children with blunt trauma is best at a pediatric trauma center. J Pediatr Surg 1996;31:72-7.
18. FARRELL LS, HANNAN EL, COOPER A. Severity of injury and mortality associated with pediatric blunt injures: hospitals with pediatric intensive care units *versus* other hospitals. Pediatr Crit Care Med 2004;5:5-9.
19. KANTER RK. Regional variation in child mortality at hospitals lacking a pediatric intensive care unit. Crit Care Med 2002;30:94-9.
20. UK Paediatric Brain Injury Study Group and the Paediatric Intensive Care Society Study Group; TASKER RC, MORRIS KP, FORSYTH RJ, HAWLEY CA, PARSLOW RC. Severe head injury in children: emergency access to neurosurgery in the United Kingdom. Emerg Med J 2006;23:519-22.
21. YATTOO GH, TABISH A. The profile of head injuries and traumatic brain injury deaths in Kashmir. J Trauma Manag Outcomes 2008;2:5. doi:10.1186/1752-2897-2-5
22. JANETT B. Epidemiology of head injury. Arch Dis Child 1998;78:403-6.
23. BOWMAN SM, BIRD TM, AITKEN ME, TILFORD JM. Trends in hospitalization associated with pediatric traumatic brain injuries. Pediatrics 2008;122:988-93.
24. LANGLOIS JA, RUTLAND-BROWN W, THOMAS KE. Traumatic brain injury in the United States. Atlanta, GA: Centers for Disease Control and Prevention, 2006.
25. KIRMANI MA, SEXENA RK, WANI MA. The spectrum of head injury in the Valley of Kashmir as seen at Sher-i-Kashmir Institute of Medical Sciences, Srinagar, Kashmir. Thesis submitted for MS (General Surgery);1986.
26. KENNEDY F, GONZALES P, ONG C, FLEMING A, SCOTT RS. The Glasgow Coma Scale. J Trauma 1993;35:75-7.
27. CASE ME. Accidental traumatic head injury in infants and young children. Brain Pathol 2008;18:583-9.
28. DUHAIME AC, EPPLEY M, MARGULIES S, HEHER K, SCOTT P. Crush injuries to the head of children. Neurosurgery 1995;37:401-7.
29. PRASAD M. Crush head injuries in infants and young children: neurologic and neuropsychiatric sequelae. J Child Neurol 1999;14:496-501.
30. CHADWICK DL, SALERNO C. Likelihood of the death of an infant or young child in a short fall of less than 6 vertical feet. J Trauma 1993;35:968.
31. HYMEL KP, BANDAK FA, PORTINGTON MD, WINTON KR. Abusive head trauma? A biomechanics-based approach. Child Maltreat 1998;3:116-28.
32. LYONS JL, OATES RK. Falling out of bed: a relatively benign occurrence. Pediatrics 1993;92:125-7.
33. OMMAYA A, GOLDSMITH W, THIBAULT L. Biomechanics and neuropathology of adult and paediatric head injury. Br J Neurosurg 2003;16:220-42.
34. BARLOW B, NIEMIRSKA M, RJINDAR P, GANDI RP, LEBLANC W. Ten years of experience with falls from a height in children. J Pediatr Surg 1983;18:509-11.
35. MUSEMECHE CA, BARTHEL M, COSENTINO C, REYNOLDS M. Pediatric falls from heights. J Trauma 1991;31:1347-9.
36. BAYKANER K, ALP H, CEVIKER N, KESKIL S, SECKIN Z. Observation of 95 patients with extradural hematoma and review of the literature. Surg Neurol 1988;30:339-41.
37. JAMIESON KG, YELLAN JD. Extradural hematoma: report of 167 cases. J Neurosurg 1968;29:13-23.
38. HAHN YS, CHUNG C, BARTHEL MJ, BALIES J, FLANNERY AM, McLONE DG. Head injuries in children under 36 months of age. Childs Nerv Syst 1988;4:34-40.

39. RIVAS JJ, LOBATO RD, SARABIA R, CORDOBES F, CABRERA A, GOMEZ P. Extradural hematoma: analysis of factors influencing the courses of 161 patients. Neurosurgery 1988;23:44-51.
40. FREYTAG E. Autopsy findings in head injuries from blunt forces. Arch Pathol 1963;75:402-13.
41. SAUVAGEAU A, BOURGAULT A, RACETTE S. Cerebral traumatism with a playground rocking toy mimicking shaken baby syndrome. J Forensic Sci 2008;53:479-82.
42. DAWSON SL, HIRSCH CS, LUCAS FV, SEBEK BA. The contrecoup phenomenon: reappraisal of a classic problem. Hum Pathol 1980;11:155-66.
43. CASE MES. Head injury in child abuse. Chapter 5. In: BRODUER AE, MONTELEONE JA, editors. St. Louis, MO: GW Medical, 1994:75-87.
44. THURMAN D, GUERRERO J. Trends in hospitalization associated with traumatic brain injury. JAMA 1999;282:954-7.
45. ADEKOYA N, THURMAN DJ, WHITE DD, WEBB KW. Surveillance for traumatic brain injury deaths: United States, 1989-1998. MMWR Surveill Summ 2002;51(10):1-14.
46. TIESMAN H, YOUNG T, TORNER JC, McMAHON M, PEEK-ASA C, FIEDLER J. Effects of a rural trauma system on traumatic brain injuries. J Neurotrauma 2007;24:1189-97.
47. CAMPBELL CG, KUEHN SM, RICHARDS PM, *et al.* Medical and cognitive outcome in children with traumatic brain injury. Can J Neurol Sci 2004;31:213-9.
48. EWING-COBBS L, FLETCHER JM, LEVIN HS, *et al.* Longitudinal neuropsychological outcome in infants and preschoolers with traumatic brain injury. J Int Neuropsychol Soc 1997;3:581-91.
49. JOHNSON DL, KRISHNAMURTHY S. Severe pediatric head injury: myth, magic, and actual fact. Pediatr Neurosurg 1998;28:167-72.
50. DONROE J, TINCOPA M, GILMAN RH, BRUGGE D, MOORE DAJ. Pedestrian road traffic injuries in urban Peruvian children and adolescents: case control analyses of personal and environmental risk factors. PLoS ONE 2008;3(9):e3166.
51. PEDEN M, *et al, **eds***. The world report on road traffic injury prevention. Geneva: WHO, 2004.
52. World Health Organization. Injury, a leading cause of a global burden of disease. Geneva: WHO, 1999.
53. AMERATUNGA S, HIJAR M, NORTON R. Road-traffic injuries: confronting disparities to address a global-health problem. Lancet 2006;367:1533-40.
54. DUPERREX O, BUNN F, ROBERTS I. Safety education of pedestrians for injury prevention: a systematic review of randomized controlled trials. BMJ 2002;324:1129.
55. FORJUOH SN. Traffic-related injury prevention interventions for low-income countries. Inj Control Saf Promot 2003;10:109-18.
56. STEVENSON MR, JAMROZIK KD, SPITTLE J. A case-control study of traffic risk factors and child pedestrian injury. Int J Epidemiol 1995;24:957-64.
57. MUELLER BA, RIVARA FP, LII SM, WEISS NS. Environmental factors and the risk for childhood pedestrian-motor vehicle collision occurrence. Am J Epidemiol 1990;132:550-60.
58. RIVERA FP, GROSSMAN DC, CUMMINGS P. Injury prevention. First of two parts. N Engl J Med 1997;337:543-8.
59. ROBERTS I, NORTON R, JACKSON R, DUNN R, HASSALL I. Effect of environmental factors on risk of injury of child pedestrian by motor vehicles: a case-control study. BMJ 1995;310:91-4.
60. ROBERTS I, MARSHALL R, LEE-JOE T. The urban traffic environment and the risk of child pedestrian injury: a case crossover approach. Epidemiology 1995;6:169-71.
61. BRUGGE D, LAI Z, HILL C, RAND W. Traffic injury data, policy, and public health: lessons from Boston Chinatown. J Urban Health 2002;79:995-8.
62. PEDEN M, TOROYAN T. Counting road traffic deaths and injuries: poor data should not detract from doing something! Ann Emerg Med 2005;46:158-60.
63. PEREL P, McGUIRE M, EAPEN K, FERRARO A. Research on prevention road traffic injuries in developing countries is needed. BMJ 2004;328:895.
64. BARTLETT SN. The problem of children's injuries in low-income countries: a review. Health Policy Plan 2002;17:1-13.
65. Traumatic Brain Injury Legislation, 2011. Available at: http://www.ncsl.org/?tabid=18687.

Sažetak

OZLJEDE GLAVE U DJECE

J. Mihić, K. Rotim, M. Marcikić i *D. Smiljanić*

U današnje vrijeme sve su učestalije ozljede glave u djece. Najčešći uzrok ozljeda glave u djece je pad, a kod težih ozljeda trauma u prometnim nesrećama. Kod traumatskih ozljeda mozga u dojenčadi i male djece najznačajniji simptomi su bljedoća, somnolencija i povraćanje, tzv. „pedijatrijski kontuzijski sindrom". Nakon prve godine života blaže ozljede glave najčešće nastaju uslijed manjih padova, a najteže ozljede su rezultat nesreća u kojima sudjeluju automobil i pješak ili padova s visine. Kako dijete raste, teške ozljede glave mnogo češće nastaju zbog biciklističkih ili automobilskih nesreća. Ozljede mozga koje nastaju nagnječenjem su kontuzije i laceracije mozga, najčešće uzrokovane prelomljenim kostima koje ozljeđuju i penetriraju mozak. Prilikom samog nagnječenja ne mora doći do gubitka svijesti, ali se nesvijest može javiti nakon razvoja otekline mozga i komplikacija zbog povišenog intrakranijskog tlaka. Unatoč opsežnim ozljedama nastalim takvim tipom nesreće ishod preživjelih je iznenađujuće dobar. Takve teže ozljede neurokranija obično uključuju teža krvarenja s hematomima (epiduralno krvarenje, subduralno krvarenje, intracerebralno krvarenje, traumatsko subarahnoidno krvarenje). Smanjenju stope smrtnosti doprinosi unaprijeđena predbolnička njega, spremnost i dostupnost multidisciplinarnih timova, uspostavljanje regionalnih centara, te pokušaji prevencije i smanjivanja broja prometnih nesreća.

Ključne riječi: *Kraniocerebralne ozljede; Dijete; Neurokirurgija; Ozljeda glave*