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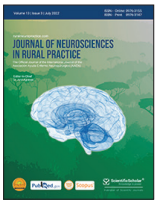

Original Article

Long-term outcome of pediatric head injuries – A five-year follow-up

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ABSTRACT

Objectives: Traumatic brain injury (TBI) disrupts the developing brain in the pediatric population. This study aims to look at the outcomes of moderate and severe TBI over a five-year follow-up to look for the long-term sequelae of head injury in the pediatric population.

Materials and Methods: A prospective observational study was conducted after obtaining the permission of the Institutional Ethics Committee with the primary study participants admitted between 2015 and 2017 with follow-up extending up to 2022 in 118 pediatric patients, aged between 1 and 15 years who required admission in the pediatric intensive care unit with moderate and severe TBI.

Results: Language impairment was noted in 33.63% (n = 37) patients during early follow-up, and 12 of them continued to have impaired language skills and communication at the end of five years. With regard to school functioning, children had more difficulty in the arithmetic domain (n = 33) compared to language domains (n = 17). While the parents noted improvements in scholastic performances, some degree of difficulty in learning was noted in most of the children, who sustained TBI. Despite these difficulties, 27 out of 41 participants, who gave their higher secondary examinations have gone on to pursue undergraduate courses in colleges.

Conclusion: Our study indicates that over the passage of time, children tend to have a reasonable chance at recovery, and with the potential for plasticity, early and aggressive rehabilitative services may enable the child to have a decent quality of life and in selected cases, even an independent life.

Keywords: Traumatic brain injury, Behavioral outcomes, Pediatrics, Scholastic performance, Quality of life

INTRODUCTION

In the pediatric population, traumatic brain injuries (TBIs) can disrupt the process of development and interfere with behavioral adjustment, knowledge acquisition, and learning new skills.[1] Despite the commonly held view that the pediatric brain has the ability to adapt to the insults sustained, several studies have demonstrated the presence of residual damage.[2,3]

Studies have suggested that in the younger population, structural damage and functional deficits are less compared to older patients, as the non damaged adjacent segments take up the functions over time. However, the principles at work in the setting of a more diffuse injury are not yet elucidated.[4-6] A counterpoint suggests that injuries disrupting the immature neural systems lead to cumulative deficits and children, with a limited established skills, may have difficulty in not just consolidation of these skills but also in acquiring new skills.[7]

Several factors have been studied to be associated with outcomes. The most significant of these is the severity of the injury. Other factors influencing outcome include age at the time of injury, pre-injury status, the socio-economic status of the parents, and access to rehabilitative care.[1,8] Very few studies look at the long-term effects of trauma on the pediatric population in India. This study aims to look at the outcomes of moderate and severe TBI over a five-year follow-up to look for the long-term sequelae of head injury in the pediatric population.

MATERIALS AND METHODS

A prospective observational study was conducted after obtaining the permission of the Institutional Ethics Committee with the primary study participants admitted between 2015 and 2017 with follow-up extending up to 2022 in 118 pediatric patients, aged between 1 and 15 years, who required admission in the pediatric intensive care unit (PICU) with moderate and severe TBI.

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Inclusion criteria

Children in the age group of 1–15 years presenting with moderate (Glasgow Coma Scale [GCS] 9–12) and severe head injury (GCS 3–8).

Exclusion criteria

Children with pre-existing neurological abnormalities.

Demographic data, history, clinical findings, radiological findings - computed tomography brain and magnetic resonance imaging in the setting of diffuse axonal injuries and management plans were documented in the pro forma. Management was carried out by consensus between the neurosurgery team and the PICU team. Outcome was assessed at discharge based on the King's Outcome Scale for Childhood Head Injury (KOSCHI). The KOSCHI scale[9] is elaborated in Table 1.

After discharge, the patients were periodically followed up. The initial follow-up was done at the first month, and subsequent follow-ups were carried out at 6 months and 12 months. After this, the patients were annually followed up in the outpatient department for the duration of the study. Patients requiring medical care in the intervening period were managed accordingly. The parents completed a questionnaire regarding the child's pre- and post-injury status using the age-specific child behavior checklist (CBCL). All the patients were followed up at 12 months post-discharge in person. Periodic follow-up either during subsequent outpatient visits or by phone interviews was carried out.

A favorable outcome was considered when the child either had a good recovery or only moderate disability based on the KOSCHI scale.

Statistical analysis was carried out with the Statistical Package for the Social Sciences version 16. Comparison was carried out with Chi-square test, and statistical significance was taken at a $P < 0.05$.

Table 1: KOSCHI.

Category		
1	Death	
2	Vegetative	The child is breathing spontaneously and may have sleep/wake cycles.
3	Severe Disability	The child is at least intermittently able to move part of the body/eyes. Implies a continuing high level of dependency
4	Moderate Disability	The child is mostly independent but needs a degree of supervision.
5	Good Recovery	Implies that the child has made a complete recovery with no detectable sequelae.

KOSCHI: King's Outcome Scale for Childhood Head Injury

Table 2: Age group and severity of TBI.

	Aged 5 and less (%)	6–15 (%)	Total
Moderate head injury	34 (55)	37 (66)	71
Severe head injury	28 (45)	19 (34)	47
Total	62	56	118

TBI: Traumatic brain injury

RESULTS

Epidemiology and presentation

A total of 118 children were admitted with TBI in our institute fulfilling the inclusion criteria. Of them, 81 were boys (68.6%) and 37 were girls. Sixty-two children (52.5%) were aged <5 years while 56 children were aged between 6 and 15 years of age. The mean age of the study population was 6.94 years. The age distribution of injuries is shown in Table 2.

With respect to the mode of injury, falls and road traffic accidents accounted for more than 90% of the injuries. While there were 60 cases of falls (51%) and 49 cases of road traffic accidents (41.5%), the latter accounted for 30 cases (61%) of severe TBI compared to 14 cases of falls (23%). Out of the nine patients who had a fall of heavy objects on their heads, three had severe head injuries.

Loss of consciousness was the most commonly noted symptom seen in nearly all patients ($n = 110$) with vomiting noted in 60% of the patients ($n = 71$). More than a third of the patients ($n = 41$) had seizures at the time of presentation. Based on the imaging characteristics, the commonest noted finding was an extradural hematoma (EDH) in 56 patients (47%). This was followed by an acute subdural hematoma (SDH) in 27 patients (23%). Other findings include traumatic intracerebral hemorrhage in 23 patients (19%) and diffuse axonal injury in 12 patients (10%).

Management

With respect to management, 57 patients (48%) underwent surgical intervention. This included 26 patients with an EDH, 20 patients with an acute SDH, nine patients with Traumatic Intracerebral Hematoma, and two patients, who were operated on for a depressed fracture. The remaining 61 patients (52%) were conservatively treated. All of the patients were initially managed in the intensive care unit. Sixty patients (51%) needed mechanical ventilation, and the mean duration of hospital stay was 12.71 days.

Outcome at discharge

The outcomes at discharge are discussed in Table 3.

Patients needing mechanical ventilation were noted to have a poorer outcome as well as longer duration of hospital stay, and both had a statistically significant correlation with $P < 0.05$. However, neither age nor gender had a correlation with outcomes at discharge. Mode of injury or the type of management-surgical versus medical did not have a statistically significant impact on the outcomes. The presence of coagulopathy and sepsis had a statistically significant correlation with poor outcomes.

Follow-up

Of the 118 children, eight died, and all of the surviving children ($n = 110$) were available for follow-up at 12 months. Ninety-eight patients (83%) were available for interview at two years post-discharge while 86 patients (72.8%) were followed up for five years. The reason for attrition ranged from the disinterest of the family ($n = 9$) to the family's inability to travel to our institute ($n = 7$) and inability to trace the family ($n = 3$). The study having been carried out over more than five years had an attrition rate of 27.1%. Sixty-eight of the patients available for long-term outcomes had a favorable outcome.

In CBCL, anxiety/depression, withdrawal, sleep, and somatic problems were considered internalizing problems while aggression and destructive behavior were seen as externalizing problems. During the follow-up visit one year post-injury ($n = 110$), 15.45% of the children ($n = 17$) had internalizing problems while 6.36% had externalizing problems ($n = 7$). At the completion of five years ($n = 86$), those with internalizing issues had tapered down to 9.30% ($n = 8$) while those with externalizing issues decreased to 4.65% ($n = 4$).

We had 14.54% ($n = 16$) patients, who showed signs of being withdrawn during the early follow-up (12 months). At five years, out of 68 children available for follow-up, 17.64% ($n = 12$) were withdrawn. Impairment of attention was noted in 42.72% ($n = 47$) children during early follow-up, and 16.17% ($n = 11$) children continued to have impaired attention at five years. With respect to memory and learning, we noted that 49.09% ($n = 54$) of children had some form of difficulty in memory and learning; however, only 20.93% ($n = 18$) continued to have difficulties at the end of five years. Out of the 18 children, who had persistent learning difficulty, 14 had sustained severe head injury before the age of five years. With respect to executive functions, we noted that at one year, 36 patients had impairment in terms of cognitive flexibility and abstract reasoning. Although some degree of improvement was noted in all the patients, 17 of them had severe difficulty in solving problems and setting goals at five years of follow-up.

Language impairment was noted in 33.63% ($n = 37$) patients during early follow-up and 12 of them continued to have impaired language skills and communication at the end of five years. With regard to school functioning, children had more difficulty in the arithmetic domain ($n = 33$) compared to language domains ($n = 17$). While the parents noted improvements in scholastic performances, some degree of difficulty in learning was noted in most of the children, who sustained TBI. Despite these difficulties, 27 out of 41 participants, who gave their higher secondary examinations, have gone on to pursue undergraduate courses in colleges.

Among the patients with unfavorable outcomes, none of them were able to continue their regular education. High incidence of cognitive disturbances, memory impairment, and language issues were noted in this subpopulation. They continued to need permanent caretakers for their day-to-day activities. Eleven of them eventually succumbed to their illness during follow-up.

Other difficulties encountered by the patients are summarized in Table 4.

Among the parents, those caring for children carrying significant disabilities, a greater proportion exhibited signs of depression and frustration. Their low morale had several factors including the fear of who would care for their disabled child after their time, the monetary constraints, and the social stigmata associated with raising a disabled child.

DISCUSSION

A multitude of factors determines the long-term outcome of patients with pediatric TBI. The most significant

Table 3: Outcome versus severity.

Severity	Poor outcome	Good outcome	Total
Moderate TBI	9	62	71
Severe TBI	26	21	47
Total	35	83	118
			P=0.001

TBI: Traumatic brain injury

Table 4: Common sequelae of TBI.

	At 3 months	At 5 years.*
Seizure	20	6
Headache	41	5
Limb weakness	21	4
Hearing impairment	11	9/9
Visual impairment	9	8
Facial weakness	19	5
Lower Cranial Nerve involvement	2	1/1

*- Of the 11 patients with a hearing impairment only nine were available for follow-up at five years and only one of the two patients with lower cranial nerve involvement was available for follow-up at five years.
TBI: Traumatic brain injury

predictor of outcome is the severity of the injury sustained.[10] The generally noted pattern of recovery is the gradual improvement over the first 12 months in the general intellectual ability of the child. Subsequent trajectories of recovery vary between children, who sustained an injury earlier and those with a later injury. The children with an early injury tend to have a poor prognosis while relatively older children make better recoveries.[8]

Studies in India have shown that boys were more commonly affected, and falls and road traffic accidents were the most common causes of TBI. In pediatric patients, acute EDH was the commonest radiological finding while loss of consciousness and vomiting were the most common presenting complaints in studies by Bhargava *et al*. and Chaitanya *et al*.[11,12] Both studies also noted a male preponderance. Chaitanya *et al*. noted that twenty-one percent of patients in their study had seizures. They noted that 31.6% of patients needed mechanical ventilation.[12] Madaan *et al*. noted that fractures of the skull were the most common radiological finding followed by EDH. While these findings are in line with the results of our study, they noted only 10.5–12.5% needing surgery[12,13] compared to the 48% noted in our study. The difference could be accounted for by the inclusion of only moderate and severe head injuries in our study while they had included mild head injuries as well. Besides, since ours is a tertiary referral center, we tend to have patients referred specifically for surgical intervention. These factors could account for the high proportion of surgeries in our study.

Contrary to previous beliefs that the young brain, being more "plastic," could recover better from injury, various lines of evidence now indicate that children, who experience injuries early in life are more susceptible to long-term deficits.[8] Children coming from socially disadvantaged groups, lower socio-economic strata, and rural areas are noted to have poor outcomes.[8,11,12] We noted that the outcome of those, who sustained injuries younger were considerably poorer than their older counterparts.

Several studies[14,15] have noted that the functional outcome is generally favorable in a majority of the patients at around 50–70%. Correlation between poor outcome and GCS, coagulopathy, sepsis, and need for mechanical ventilation and younger age have been noted by several authors.[8,10,11] Similar findings were noted in our study. Deficits of attention depend not only on the location of the injury but also on the stage of development the child is in at the time of insult.[16] Studies have shown skills emerging at the time of injury are affected more.[17] It has been shown that except in very severe injuries, impaired memory usually shows improvement. Given how even then the memory problems are only for complex memories, memory shows fairly good recovery.[8,16]

The impact of TBI on the subcomponents of executive function (working memory, cognitive flexibility, and inhibitory control) in children can vary based on factors such as age at injury, injury severity, and ongoing neural and cognitive development. Severe injuries generally lead to weaker executive skills compared to milder injuries. The age at which the injury occurs is crucial for recovering from executive impairments since the frontal lobes, essential for developing these skills, undergo an extended developmental process until late adolescence/early adulthood, marked by neural growth and myelination periods aligning with improved cognitive function.[18] We noted that less than half of our patients showed improvement in executive function over five years.

Numerous studies have examined functional and pragmatic language impairments following head injury. These impairments can hinder children's effective communication in day-to-day situations, leading to social challenges. The difficulties may arise from struggles in understanding abstract or metaphorical language and humor, as highlighted by Turkstra *et al*.[19] More than a third of the patients, who were followed up for five years had impairment of language function while all of them showed improvement of language function for follow-up.

Some issues arise as a consequence of untreated emotional and behavioral issues directly as a result of the injury, while others may result from impaired skills such as executive dysfunction or inadequate communication skills.[2] Growing evidence also suggests deficits in certain aspects of social cognition, leading to reduced social competence. Such difficulties were commonly seen in our study participants, who seemed to show marginal improvement with time. Individuals with childhood TBI may struggle with attributing intent and making inferences about the mental states of others, demonstrated by challenges in the theory of mind, as observed in studies like those by Snodgrass and Knott[20] and Walz *et al*.[21]

Our study is limited by the fact that it is a single-center study with the limitation of sample size. Although not many studies have addressed the issues studied here, we hope to continue this study for the foreseeable future to have a longer duration of the assessment and more patients.

CONCLUSION

A complex interplay of factors influences recovery after childhood TBI, making outcomes unpredictable and highly variable. Cognitive impairments are influenced by factors such as age at the time of injury, location as well as severity of the injury.

Our study indicates that over the passage of time, children tend to have a reasonable chance at recovery, and with the potential for plasticity, early and aggressive rehabilitative services may enable the child to have a decent quality of life and in selected cases, even an independent life.

Authors' contribution

Sai Sriram Swamiyappan: Data curation, Writing an original draft, formal analysis, validation, software. Pinnaka Subba Rao: Writing-review and editing, data curation. Sree Apoorva Puttagunta: Methodology, investigation, data curation. Ramachandran Padmanabhan: Conceptualization, supervision. Vivek Visveswaran: Project administration, resources.

Ethical approval

The research/study was approved by the Institutional Review Board at Institutional Ethics Committee, SRMC, number CSP-MED/15/AUG/24/10, dated 21.08.15.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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