



Surgical management of traumatic extradural hematomas in children: an analysis of 201 patients at a tertiary neurosurgical center

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Abstract

Introduction The effects of traumatic extradural hematoma (EDH) are potentially reversible if treated early. Pediatric EDH differs from its adult counterpart because of the differential elastic and adherence properties of skull bone and dura respectively. There is a paucity of literature regarding prognosis and factors predicting the outcome of pediatric EDH. In this study, we aimed to study the factors predicting outcome and prognosis of traumatic EDH in the pediatric age group.

Materials and methods We did a retrospective chart review of all pediatric EDH operated in our center between 2011 and 2017. Factors affecting prognosis were analyzed through univariate and multivariate analyses.

Results Two hundred one patients qualified for the study. There were 159 boys and 42 girls with a sex ratio of 3.78:1. The most common modes of injury were road traffic accidents ($n = 108$, 53.3%) followed by falls from a height. The most common clinical presentation was vomiting ($n = 168$, 83.3%), followed by headache ($n = 72$, 35.8%). Pupillary asymmetry was present in 11.4% ($n = 23$) patients. The mean GCS at presentation was 12.71. The mean volume of EDH was 37.18 cc, with a mean maximum thickness of 23.19 mm. The most common location of the EDH was at temporoparietal region ($n = 67$, 33.3%). The median time of diagnosis from injury was 14.69 h (SD, 32.9 h). The mean GCS at discharge was 14.43 (SD \pm 0.51). Sixteen patients were lost to follow; 185 patients were available for follow-up and were included in the outcome analysis. The mean GOS at follow-up was 4.9 (SD \pm 0.368) with a median follow-up of 13.46 months. In our cohort, only one child died. Univariate and multivariate analyses revealed that pupillary asymmetry, pyramidal signs, low GCS at presentation, associated parenchymal injuries, and post-operative complications correlated negatively with outcome, whereas vomiting correlated positively with outcome.

Conclusion Pediatric EDH differs from adults in complications as well as outcome. EDH in this pediatric cohort had a better outcome with very less mortality. Increased transportation facilities and the industrial revolution may have facilitated the shift of mode of injury from fall of height in the past to road traffic accidents in this study. A large study comparing the outcomes with pediatric and adult patients is warranted.

Keywords Extradural hematoma · Pediatric head injury · Glasgow coma scale · Glasgow outcome score

Introduction

Extradural hematomas (EDH) comprise 2.7–4% [1] of traumatic brain injuries. It is a potentially reversible condition

with early intervention. Post-traumatic EDH in the pediatric age group occurs less frequently when compared with adult population in the community. Increased EDH incidence in the last decade could be accounted for by rapid urbanization and the availability of imaging in developing countries. Mode of injury, prognostic factors, and outcome vary significantly in children when compared with adults. In this study, we attempt to review all cases of EDH in the pediatric age group, operated in our institute over the last 7 years to predict factors that determine outcome.

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Materials and methodology

We did a retrospective chart review of all pediatric EDH cases from prospectively maintained operative database in our institute between 2011 and 2017. Factors including mode of injury, time from the onset of trauma to surgery, age, sex ratios, GCS at presentation, and discharge were included in the analysis. Findings on CT head, presence of mass effect and midline shift, uncal herniation, volume of EDH, and associated injuries including scalp hematoma, skull fractures, and parenchymal injuries were noted. A decision regarding surgery was taken based on brain trauma foundation guidelines including volume > 30 cc, midline shift >5 mm, children with excessive irritability, altered sensorium, and bradycardia. Indications for posterior fossa EDH included mass effect over fourth ventricle causing distortion/displacement and brain stem compression. GOS (Glasgow outcome scale) at follow-up was assessed. Multivariate and univariate analyses using Spearman's correlation coefficient are used to predict the factors of outcome (Fig. 1).

Results

A total of 201 cases with age less than 18 years were included in the study. Demographics and clinical data were tabulated and analyzed (Table 1). Age at the presentation ranged from a minimum of 2 years to a maximum of 18 years with a mean age of 11.87 years. We divided the age in four groups: group 1 from 0 to 2 years, group 2 includes 3–5 years, group 3 includes 6–12 years, and group 4 includes 13–18 years. Majority of children in our cohort belonged to subgroup 4 ($n = 102$, 50.7%). Out of 201 children, 159 were boys and 42 were girls with sex ratio of 3.78:1.

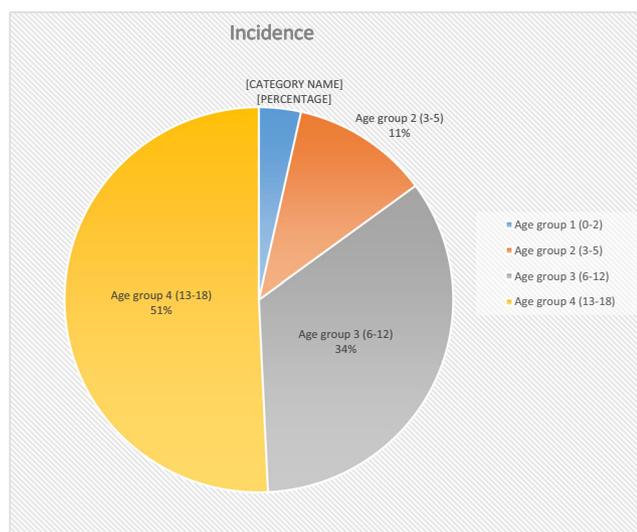


Fig. 1 Pie diagram representing the different age groups and their incidence

Table 1 Breakup of operated pediatric EDH in different age groups, sex, and mode of injury

Age	
Group 1 (0–2 years)	7 (3.5%)
Group 2 (3–5 years)	23 (11.4%)
Group 3 (6–12 years)	69 (34.3%)
Group 4 (13–18 years)	102 (50.4%)
Sex (male/female)	159/42
Mode of injury	
RTA	108 (53.3%)
Fall from height	75 (35.7%)
Fall of object on head	5 (2.48%)
Assault	9 (4.4%)

The most common mode of injury in our study was by road traffic accident—including self-driving, pillion riders, and traveling in vehicles as passengers ($n = 108$, 53.73%). Next most common type of injury was fall from height greater than 5 ft. ($n = 59$, 29.3%). Assault history was found in 6 children (0.02%). The mode of injury with different age groups was represented in a bar diagram (Fig. 2).

The most common clinical presentation was persistent vomiting ($n = 168$, 83.6%) followed by severe headache ($n = 72$, 35.8%). History of loss of consciousness at the time of injury was found in 63.2% ($n = 127$), although majority of the patients are conscious at the time of presentation. The mean Glasgow coma score (GCS) at presentation was 12.71. Pupillary asymmetry was found in 11.4% ($n = 23$) which correlated with imaging findings, after excluding local injuries. Neurological deficits including pyramidal signs indicating herniation/compression of cerebral peduncles was present in 4% ($n = 8$) of the patients.

All these patients were evaluated with CT scan, other relevant radiographic, and blood investigations required following their presentation to the emergency room (Fig. 3). The mean volume of EDH was 37.18 cc, with mean maximum thickness value of 23.19 mm. Associated skull fracture was found in 64.17% ($n = 129$) and other parenchymal injuries like contusion in 17 children (8.4%), although none of the patients in this study underwent removal of contusions. The most common location of the EDH was at temporoparietal region ($n = 67$, 33.3%) followed by frontal region ($n = 49$, 24.4%). The mean time from injury to diagnosis was 14.69 h with a median of 6 h. Mean time from injury to surgery was 21.72 h with a median of 10 h. The delay in time to surgery from diagnosis was most probably due to referral from primary center to our center for further care. All patients underwent craniotomy and evacuation of extradural hematoma, followed by elevation of dura by hitching it along the edges as well as from the central areas. Dura was not opened in any of these cases in the study. Subgaleal drains were used in all cases and are removed on first or second post-operative days based on drain output. The mean operating time was 1.3 h with SD ± 0.51 . The mean

Fig. 2 Bar diagram representing of mode if injury in different age groups

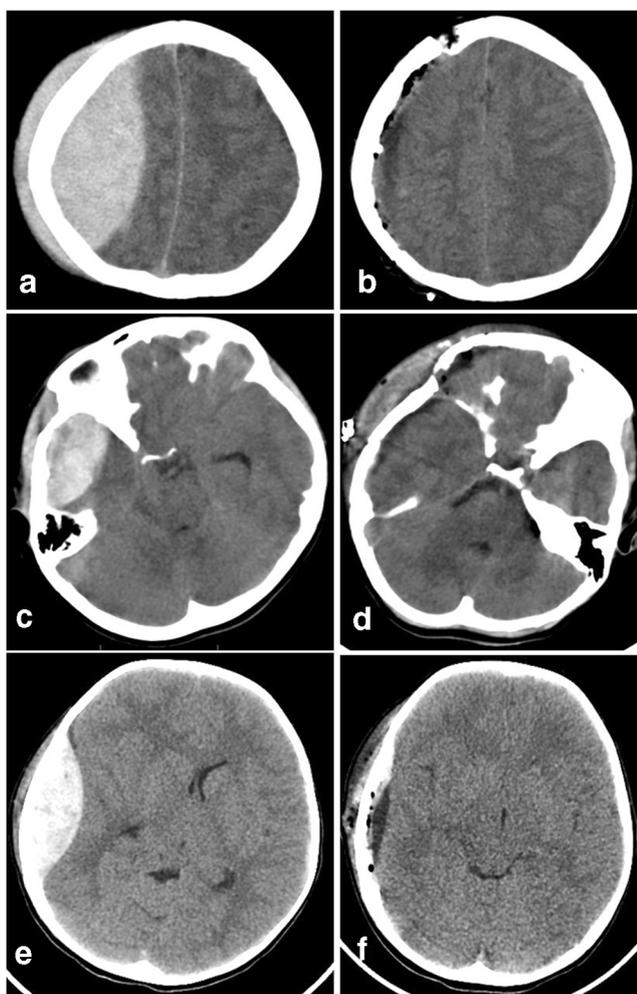
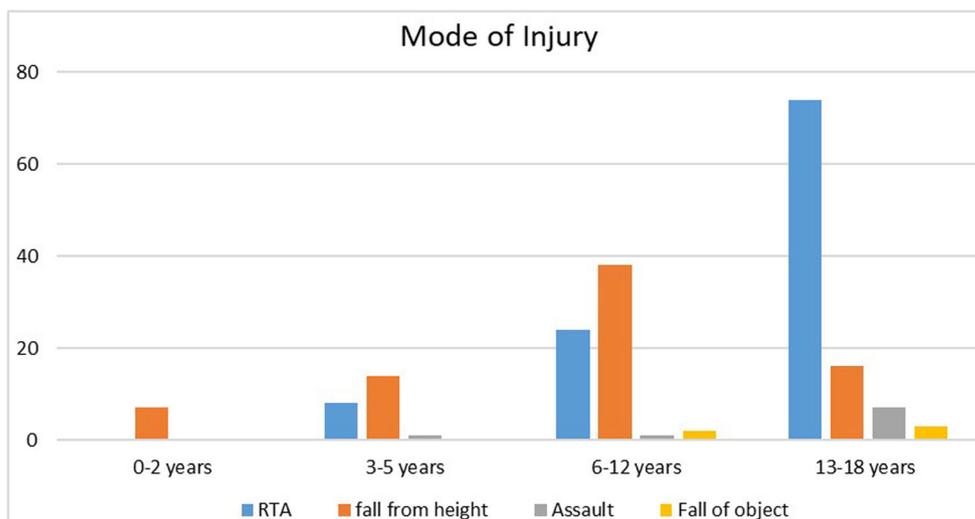


Fig. 3 **a** Computer tomogram (CT) of 15-year-old child with traumatic right fronto-parietal extradural hematoma (EDH) and **b** post-operative CT after surgery. **c** CT of an 8-year-old child with the right basitemporal EDH and **d** post-operative scan after evacuation of hematoma. **e** CT of 3-year-old child with the right frontotemporal EDH and **f** post-operative scan after evacuation

duration of hospital stay was 1.72 days ($n = 139, 69.2\%$). Patients were deemed to be fit to discharge if they were fully conscious without any other intracranial injuries like contusions or edema in the post-operative scan done the next day. Mean GCS at discharge was 14.43 with $SD \pm 0.51$. Post-operative complications including re-exploration due to re-collection, subdural hygroma and infection was found in 12 children (0.05%) (Tables 2 and 3).

Sixteen patients were lost to follow-up. A total of 185 patients were followed up at a median of 13.46 months. The mean Glasgow outcome scale (GOS) at follow-up was 4.9 ($SD \pm 0.368$). The majority of patients were in GOS 5 group ($n =$

Table 2 Clinical and radiological features of pediatric patients operated for EDH

Clinical characteristics	
Vomiting	$N = 168, (83.6\%)$
Headache	$N = 72, (35.8\%)$
Loss of consciousness	$N = 127, (63.2\%)$
Mean GCS at presentation	12.71
Pupillary asymmetry	$N = 23, (11.4\%)$
Pyramidal signs	$N = 8, (4\%)$
Imaging characteristics	
Location	
Temporoparietal	67 (33.3%)
Frontal	49 (24.4%)
Occipital	4 (2%)
Posterior fossa	10 (5%)
Supra- and infratentorial	1
Mean volume	37.18 cc
Mean maximum thickness	23.19 mm
Associated parenchymal injuries	$N = 17, (8.4\%)$
Mean time of injury to diagnosis	14.69 h
Mean time from injury to surgery	21.72 h

Table 3 Table showing mean operative time, hospital stay, and outcome characteristics pediatric patients operated for EDH

Mean operative time	1.3 h ± 0.51±
Mean duration of hospital stay	1.72 days
Mean GCS at discharge	14.43 ± 0.51
Post-operative complications	N = 12, (0.05%)
Follow-up	13.46 months
Mean GOS at follow-up	4.9 ± 0.368

173, 86.06%). Problems at follow-up were present in 14.9% (30) which included chronic headache, recurrent seizures, wound infections, cosmetic deformities, and residual weakness.

Univariate and multivariate analyses (Spearman correlation coefficient ratio) were used to predict factors affecting outcome. These were analyzed based on the duration of hospital stay, GCS at discharge, and GOS at follow-up. The factors predicting duration of stay were pupillary asymmetry, vomiting before presentation, GCS at presentation, presence of parenchymal injuries, and time from injury to diagnosis, post-operative complications, and minor problems at follow-up. After multivariate analyses, factors predicting outcome, i.e., GOS at follow-up were pupillary asymmetry, vomiting, initial GCS at presentation, other parenchymal injuries, and post-operative complications. Interestingly, vomiting has a positive correlation in our group. Patients with vomiting as a part of their clinical presentation had better outcomes at follow-up. We hypothesize those patients with vomiting reach

medical attention faster than patients without these symptoms. All factors correlating with outcome are mentioned in Tables 4, 5, and 6.

Discussion

Incidence of EDH in pediatric patients was found to be between 2.7 and 4% [1–3]. Although it constitutes a very small percentage of pediatric head injuries, it causes significant socioeconomic burden. EDH has very favorable cost-benefit ratio compared to other traumatic brain injuries. Mohanty et al. in a study from the same institute reported a high incidence of pediatric EDH (20%) compared to other series [4, 5]. Children with mild head injury may harbor EDH without any significant symptoms initially. Munivenkatappa et al. from the same institute, studied the factors that predict an abnormal CT scan in children with mild head injury. In their study, they could not rule out an abnormal CT finding based on the clinical examination findings [6], which emphasize the fact that we need to have a low threshold to screen children with head injury with CT brain.

The most common mode of injury in our study was road traffic accident (RTA) ($n = 108$, 53.3%), unlike other series where fall from height is the commonest. Fall from height is the next most common mode of injury after road traffic accidents in our series ($n = 59$, 23.3%) [7, 8]. This may be attributed due to increased industrialization with improper safety

Table 4 Table analyzing factors predicting the duration of the hospital stay for pediatric patients operated for EDH

	Factors	Correlation coefficient (Spearman's ratio)	<i>p</i> value
Duration of hospital stay	Age group	0.046	0.518
	Sex	0.098	0.171
	MOI	0.009	0.913
	Loss of consciousness	0.132	0.065
	Headache	−0.081	0.256
	Pyramidal	0.049	0.490
	Pupillary asymmetry	0.164	<i>0.021</i>
	Vomiting	−0.204	<i>0.004</i>
	Location	0.010	0.883
	GCS at initial presentation	0.350	< <i>0.001</i>
	Other parenchymal injury	0.263	< <i>0.001</i>
	Post-operative complications	0.323	< <i>0.001</i>
	Skull fracture	0.024	0.765
	Minor problems at follow-up	0.219	<i>0.002</i>
	Maximum thickness (mm)	0.071	0.450
	Time from injury to diagnosis (h)	−0.195	<i>0.006</i>
Time from injury to surgery (h)	−0.119	0.095	
Operative time	0.045	0.531	

p value less than 0.05 is considered significant in statistical analysis. All the values less than 0.05 are indicated in italics

Table 5 Table analyzing factors predicting the outcome in means of GCS at discharge for pediatric patients operated for EDH

	Factors	Correlation Coefficient (Spearman’s ratio)	<i>p</i> value
GCS at discharge	Age group	− 0.120	0.092
	Sex	− 0.134	0.059
	MOI	− 0.021	0.794
	Loss of consciousness	− 0.121	0.088
	Headache	0.221	<i>0.002</i>
	Pyramidal signs	− 0.160	<i>0.024</i>
	Pupillary asymmetry	− 0.287	< <i>0.001</i>
	Vomiting	0.202	<i>0.004</i>
	Location	0.023	0.753
	GCS at presentation	− 0.366	< <i>0.001</i>
	Other parenchymal injury	− 0.307	< <i>0.001</i>
	Post op complications	− 0.236	<i>0.001</i>
	Skull fracture	0.136	0.084
	Minor problems at follow-up	− 0.106	0.140
	Maximum thickness (mm)	− 0.078	0.409
	Time from injury to diagnosis (h)	0.018	0.805
	Time from injury to surgery (h)	0.050	0.488
	Operative time	− 0.104	0.146

p value less than 0.05 is considered significant in statistical analysis. All the values less than 0.05 are indicated in italics

regulations for children. In RTAs, two-wheeler rider hit by another vehicle was the commonest (13.4%), stressing the fact of growing underage driving. Most of the children in our

cohort belonged to 13- to 18-year subgroup (*n* = 102, 50.7%). RTAs were considered as high velocity injuries following impact which may cause significant injury although

Table 6 Table analyzing factors predicting the GOS at follow-up for pediatric patients operated for EDH

	Factors	Correlation coefficient (Spearman’s ratio)	<i>p</i> value
GOS	Age group	− 0.106	0.207
	Sex	− 0.102	0.224
	MOI	− 0.082	0.401
	Loss of consciousness	0.029	0.726
	Headache	0.065	0.440
	Pyramidal symptoms	− 0.077	0.358
	Pupillary asymmetry	− 0.351	< <i>0.001</i>
	Vomiting	0.305	< <i>0.001</i>
	Location	− 0.036	0.671
	GCS at initial presentation	− 0.207	<i>0.013</i>
	Other parenchymal injury	− 0.341	< <i>0.001</i>
	Post op complications	− 0.418	< <i>0.001</i>
	Skull fracture	− 0.004	0.965
	Minor problems at follow-up	− 0.165	0.051
	Maximum thickness (mm)	− 0.203	0.077
	Time from injury to diagnosis (h)	0.128	0.127
	Time from injury to surgery (h)	0.127	0.131
	Operative time	− 0.121	0.150

p value less than 0.05 is considered significant in statistical analysis. All the values less than 0.05 are indicated in italics

associated parenchymal injuries were less common in our cohort. Assault history (pediatric abuse) cannot be overlooked in our cohort, although it constitutes for a small percentage. In our series, the mechanism of injury did not correlate with the outcome and did not affect the hospital stay ($p = 0.913$ for hospital stay, $p = 0.79$ for GCS at discharge, $p = 0.40$ for GOS at follow-up) which differs from other series. Zhong et al. in their study found that fall from height > 3 m had significantly poorer outcome and increased mortality rate compared to other types [3]. Low incidence of EDH compared to adults may be attributed to differences in dura adherence to bone [5, 7, 8].

Associated parenchymal injuries with EDH in pediatric cohort constitute a smaller percentage ($n = 17$, 8.4%). Although the most common mode of injury (RTA) is high velocity type, the associated parenchymal injuries in the brain were sparse. Though the most common associated injury was contusion, craniotomy was not required in any patient in our cohort. Association of parenchymal injuries was a significant poor predictor of outcome in our cohort ($p < 0.001$) [9–14].

The most common location of EDH in our series is temporoparietal region (33.3%), followed by frontal (24.4%), and combined together constituted more than half of the cases. We did not find any correlation between the location and prognosis/outcome ($p = 0.671$). We were in agreement with Mohanty et al., with similar findings [5]. In contrary, according to Chowdhury et al., frontal EDH has better prognosis than other areas [15]. Location of the EDH is similar in other major studies as well. Associated skull fractures were found in 129 patients (64.4%). Presence of skull fractures was not associated with outcome at discharge or follow-up ($p = 0.08$, 0.96 respectively), although the presence of skull fracture can facilitate the seepage of blood to extra cranial cavity through the displaced fracture decreasing the intracranial pressure. Pediatric skulls are generally more resilient for fracture than adults [16]. EDH generally does not cross sutures, sometimes they can and they do cross the suture although it does not affect the prognosis of the patients [16].

Vomiting is the most common symptom in pediatric EDH cases (83.3%), followed by headache (35.8%). Interestingly, in our cohort, we found vomiting to have a positive correlation with outcome (correlation coefficient = 0.202, $p = 0.004$). Our hypothesis is that children with vomiting seek medical attention faster than others and receive more aggressive evaluation. Pupillary asymmetry was found in 23 cases (11.4%) at presentation and is associated with poor outcome ($p < 0.001$, correlation coefficient = -0.287). Altered sensorium was not found in the majority of our patients, which differ from other studies [3, 7, 9, 17]. Pyramidal signs were present in 4% and associated with poor outcome ($p = 0.024$). This can be attributed to uncal herniation and compression of cerebral peduncles due to edema or mass effect. Loss of consciousness was found in 127 patients (63.2%). Most of the signs and symptoms for pediatric EDH

cases were non-specific and may not present with raised ICP signs rather than non-specific headache and vomiting, as children tolerate increase in ICP better than adults which may result in lesser signs and symptoms [16].

Outcome was based on GCS assessed at discharge, GOS at 6 months follow-up, or last follow-up. The mean GOS was 4.90 (SE ± 0.31). Pupillary asymmetry at presentation, vomiting, GCS at presentation, presence of parenchymal injuries, and post-operative complications adversely impacted both time to discharge and outcome at follow-up. Mortality in pediatric EDH ranges from 0 to 17% as per literature [5]. In our cohort, only one child died. In an earlier series from our department [5], mortality was around 10% which was in agreement with other major series [7, 9, 17, 18]. Decrease in mortality may be due to faster transportation in which the patient can reach the neurosurgery ER earlier compared to past, although the mean time from injury to surgery (21.72 h.) did not show any correlation with outcome. EDH in this pediatric cohort had a better outcome with very less mortality although some have reported that Younger children have poor outcome compared to adults [19, 20].

Conclusion

Extradural hematomas in the pediatric age group are most commonly located at temporoparietal region. Children with pupillary asymmetry and pyramidal signs had worse prognosis compared to others. Patients with higher GCS score had good outcome, and associated parenchymal injuries had poor prognosis. The shift of mode of injury from fall from height to RTA is most likely due to increased accessibility of motor vehicles to the adolescent age group. EDH in this pediatric cohort had a better outcome with very less mortality, although a comparative study with adults is warranted.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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