Original Article

Postoperative cerebral infarction after evacuation of traumatic epidural hematoma in children younger than two years: Single-center experience

Mohammed Fathy Adel Ali[1], Mohammad Elbaroody[1], Mohamed F. M. Alsawy[1], Ahmed El Fiki[1], Ehab El Refaee[1,2], Hesham A. Elshitany[1]

[1]Department of Neurosurgery, Faculty of Medicine, Cairo University, Cairo, Egypt, [2]Department of Neurosurgery, Greifswald Medical School, University of Greifswald, Greifswald, Germany.

E-mail: Mohammed Fathy Adel Ali - dr.mohamedfathy2006@gmail.com; *Mohammad Elbaroody - mohammad.elbaroody@kasralainy.edu.eg; Mohamed F. M. Alsawy - mohamed.elsawy@kasralainy.edu.eg; Ahmed El Fiki - asfiki@yahoo.com; Ehab El Refaee - e.elrefaee@googlemail.com; Hesham A. Elshitany - hisham.elshitany@kasralainy.edu.eg

*Corresponding author:
Mohammad Elbaroody,
Department of Neurosurgery,
Cairo University Hospitals,
Cairo University, Cairo, Egypt.

mohammad.elbaroody@
kasralainy.edu.eg

ABSTRACT

Background: Epidural hematoma (EDH) forms about 2–3% of all head injuries in the pediatric population. We evaluated clinical data and risk factors for postoperative infarction in children younger than 2 years presented with traumatic EDH.

Methods: We retrospectively reviewed and analyzed the data of 28 children with traumatic EDH operated in our institute during a period of 26 months (from December 2016 to Febuary 2019).

Results: Nineteen children were boys (68%) and nine were girls (32%), the mean age was 15 months (range from 5 to 24 months). Postoperative cerebral infarction was detected in seven cases (25%). Factors could be linked to postoperative cerebral: preoperative pediatric Glasgow Coma Scale ($P = 0.036$), neurological deficit on admission ($P = 0.023$), size of hematoma ($P < 0.001$), time between trauma and surgery ($P = 0.004$), midline shift (MLS) ($P = 0.001$), and basal cistern compression ($P = 0.004$).

Conclusion: Traumatic EDH in young children represents a neurosurgical challenge that needs rapid surgical intervention for the best surgical outcome. Delay in the time of surgery for more than 6 h, large hematoma volume >100 ml³, MLS >10 mm, and basal cisterns compression will push the intracranial pressure to the point of decompensation and the resultant ischemic sequel occurs.

Keywords: Epidural hematoma, Extradural hematoma, Head injury, Infants, Infarction

INTRODUCTION

Epidural hematoma (EDH) is a common type of traumatic brain injury in adults but it represents a rare clinical and pathological entity in children.[10] EDH forms about 2–3% of all head injuries in the pediatric population and the incidence of EDH is even less encountered among infants under the age of 12 months.[2,8,14,18,21] Accumulation of blood in the extradural space compressing the brain might lead to brain herniation and/or cerebral infarction with subsequent poor neurological outcome, but in infants, the high compliance of the cranial vault and brain could count against the

increased pressure accompanying the EDH.[19,24] Evacuation of hematoma as early as possible could prevent this sequela and help to relieve compression from the brain.[6,26] Although up to 50% of infants with EDH could have anemia, the related ischemic complications are still rare.[16,24] In this study, we retrospectively reviewed factors that could be linked to postoperative cerebral infarction among 28 children <2-years-old after acute traumatic EDH evacuation.

MATERIALS AND METHODS

Patients

We retrospectively reviewed and analyzed the collected data of 28 children under the age of 2 years with traumatic acute EDH who were surgically treated in our institute during a period of 26 months (from December 2016 to February 2019). We specified inclusion and exclusion criteria for patients to be encountered in this study, the inclusion criteria were: (1) pediatric age group ≤2 years, (2) computed tomography (CT) brain without contrast showing evidence of traumatic EDH, and (3) EDH managed with craniotomy in our department. Exclusion criteria were: (1) children older than 2 years, (2) coexistent subdural hematoma, brain contusions, or lacerations, (3) patients operated outside our institute.

Radiological criteria

CT brain was done for all children before admission.[15] Hematoma volume was calculated according to Coniglobus' formula; (length × width × height)/2, length and width were measured in the CT cut that showed the largest hemorrhage area.[22,27] The midline shift (MLS) from the septum pellucidum plane was calculated by measuring the perpendicular dimension from the center of the septum pellucidum to the virtual line connecting the central inner ridges of both frontal and occipital skull bone. Basal cisterns around the midbrain were assessed for compression.

Clinical indices

We evaluated 12 clinical indices: gender, age, mode of trauma, clinical presentation, preoperative pediatric Glasgow Coma Scale (GCS), the neurological deficit on admission, preoperative hemoglobin level, location of EDH, the volume of hematoma, basal cisterns morphology, midline shift, and timing from trauma to surgery.

Treatment

Indications for emergency surgery were based on the following: (1) an EDH >30 ml³ with 15-mm thickness and more than a 5-mm MLS and (2) hematoma with a maximum diameter of more than 18 mm and MLS more than 5 mm.[4,7]

All cases were operated by craniotomy to evacuate the hematoma with standard neurosurgical techniques followed by dural hitch stitching and bone flap replacement in place. All the cases needed blood transfusion intraoperatively with variable amount according to the amount of blood loss, this was owed to small body mass with low threshold for uneventful events in this age group with blood loss, and most of those cases already had low preoperative hemoglobin due to lost amount of blood in the hematoma and subgaleal space.

Postoperative CT brain was done for patients on the 1st and 7th day and postoperative cerebral infarction was identified as a low-density area along with distribution of posterior cerebral artery (PCA) as a sequela for uncal herniation.

The mean time for follow-up in our series was 5 months (from 4 to 6 months), where we followed the clinical status of the patients who developed infarction and started on physiotherapy.

Ethics approval and consent to participate

Patient confidentiality was kept following the Helsinki Declaration. Due to its retrospective nature, ethical board approval was not obtained, especially that there were no specific interventions for the patients enlisted in our study.

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient's guardian has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patient's guardian understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Statistical analysis

Microsoft Excel® 2013 (Microsoft® Corporation, Redmond, WA) was used for data entry and the Statistical Package for the Social Science (SPSS®, Armonk, New York: International Business Machines Corporation) was used for data analysis. All collected data were revised for competencies and logical consistency. Simple descriptive statistics (arithmetic mean and standard deviation) are used for the summary of normal quantitative data and frequencies used for qualitative data. The bivariate relationship was displayed in cross-tabulations and a comparison of proportions was performed using the Chi-square and Fisher's exact tests where appropriate. An independent *t*-test was used to compare normally distributed quantitative data. Those factors that were significantly associated with infarction in bivariate analysis ($P < 0.05$) were included in multivariate logistic regression models. The level of significance was set at a probability $P < 0.05$.

Case presentation

Case 1

A 6-month-old male child falls from a height on his head presented with a decrease in consciousness level, CT brain was done and showed a large right temporoparietal occipital EDH [Figure 1]. Pediatric GCS at admission was 12/15, preoperative hemoglobin was 8.3 g/dl, and timing to surgery was 4 h after head trauma. Preoperatively, the pupil was rounded, reactive, and regular (RRR). Complete evacuation of hematoma was done, postoperative hemoglobin was 10.5 g/dl, with no additional blood transfusion was given. Postoperatively, the pupil was RRR, and the GCS was 15/15; the patient was discharged home in the 4th postoperative day in good condition without neurological deficit.

Case 2

An 8-month-old male child falls from a height on his head presented with a decrease in consciousness level, CT brain was done and showed a large right temporoparietal occipital EDH with active bleeding [Figure 2]. Pediatric GCS at admission was 8/15, preoperative hemoglobin was 7.4 g/dl, and timing to surgery was 6.5 h after head trauma. Preoperatively, the right pupil was regular, dilated, and unreactive to light; and the left was RRR. Complete evacuation of hematoma was done, postoperative hemoglobin was 9.9 gm/dl, with no additional blood transfusion was given. At the 2nd postoperative day, the right pupil was RRR, and the GCS was 15/15 at time of discharge; the patient was discharged home in the 5th postoperative day, he developed left-sided weakness postoperatively which was improved gradually after physiotherapy when he came for follow-up later on.
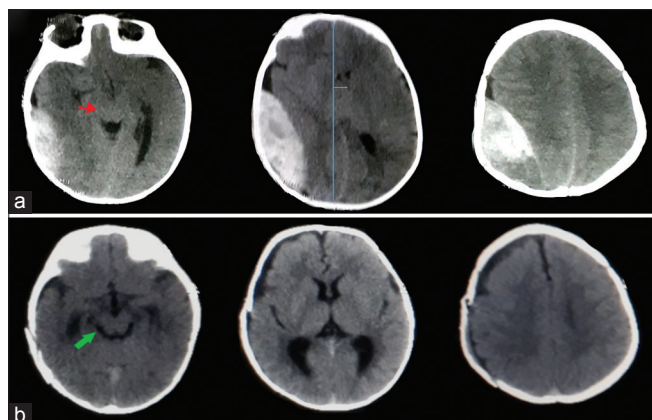

Figure 1: CT brain, axial cuts without contrast (a) right temporoparietal occipital epidural hematoma, red arrow; brainstem and cisternal compression, and blue and yellow lines highlight the midline shift. (b) Postoperative CT after hematoma evacuation, green arrow points to relief of brainstem after surgery.

Case 3

A 9-month-old female child falls on the ground presented with repeated vomiting, CT brain done and showed a large right temporoparietal EDH [Figure 3]. Pediatric GCS at admission was 15/15, preoperative hemoglobin was 6 g/dl, and timing to surgery was 5 h after head trauma. Preoperatively, the right pupil was regular, dilated, and unreactive to light; and the left was RRR. Complete evacuation of hematoma was done, postoperative hemoglobin was 10.2 g/dl, with no additional blood transfusion was given. In the same operative day, the right pupil was RRR, and the GCS was 15/15 at time of discharge; and the patient was discharged home in good condition without neurological deficit in the 4th postoperative day.

RESULTS

Patient's characteristics

Nineteen children were boys (68%) and nine were girls (32%), the mean age was 15 months (range from 5 to 24 months), the mean pediatric GCS on admission was 12 (range from 5 to 15), the most common mode of trauma was domestic fall from a height which happened in 27 cases, and only one child came in a road traffic accident. Repeated vomiting was the main symptom in 16 children (57%) while loss of
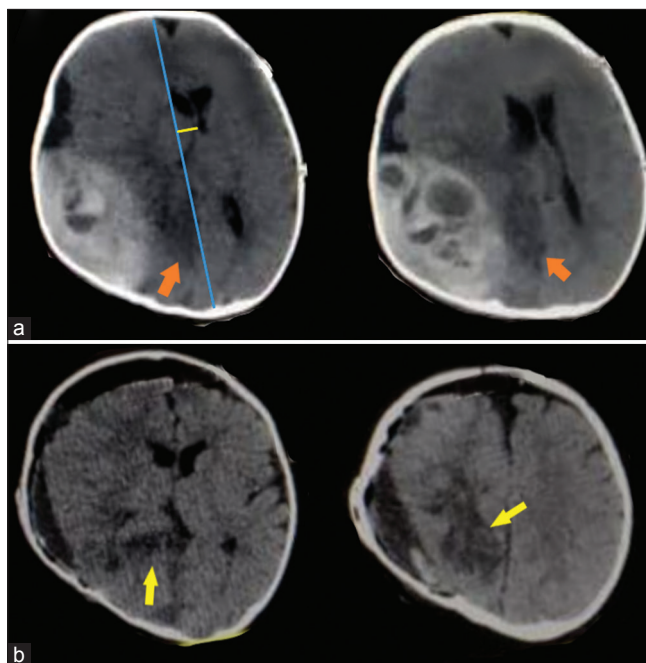

Figure 2: CT brain, axial cuts without contrast, (a) right temporoparietal hyperacute epidural hematoma with active bleeding, orange arrows hypodense areas in distribution of posterior cerebral artery from severe compression due to herniation of temporal lobe, and blue and yellow lines highlight the midline shift. (b) Postoperative CT, yellow arrows point to the infarction in the form of hypodense areas.

consciousness was the presentation in the other 12 cases (43%). The time interval between trauma and surgery varied from 3 to 16 h (mean 5.4 h).

Gender, age, mode of trauma, and clinical presentation had no statistically significant relation to postoperative infarction (P = 0.243, 0.823, 0.557, and 0.078, respectively). The mean preoperative hemoglobin was 8.89 g/dl (average from 3.9 to 11.8 g/dl) (P = 0.093).

The pediatric GCS on admission is strongly correlated with postoperative infarction (P = 0.036). On discharge, the GCS turned out to be independent of the initial GCS after trauma whenever the initial GCS was 6 or more, so that 27 cases recovered completely, and one case discharged in the vegetative state (P =0.006).

19/21 of patients who did not develop infarction operated on within 3–6 h, while 4/7 of patients who developed infarction were operated on after 6 h from the time of trauma (P = 0.004).

At the time of presentation, 20/21 (92.2%) of patients who did not develop infarction and 4/7 (57.1%) of patients who developed infarction did not show any neurological deficit (P = 0.023).

Radiological data

The hematoma was related to the temporal lobe (temporal, temporoparietal, temporoparietal-occipital, and frontotemporal) in 14 cases (50%) and it was away from the temporal lobe in the other 14 cases. The mean volume of hematoma was 72.75 ml^3 (range from 30 to 140
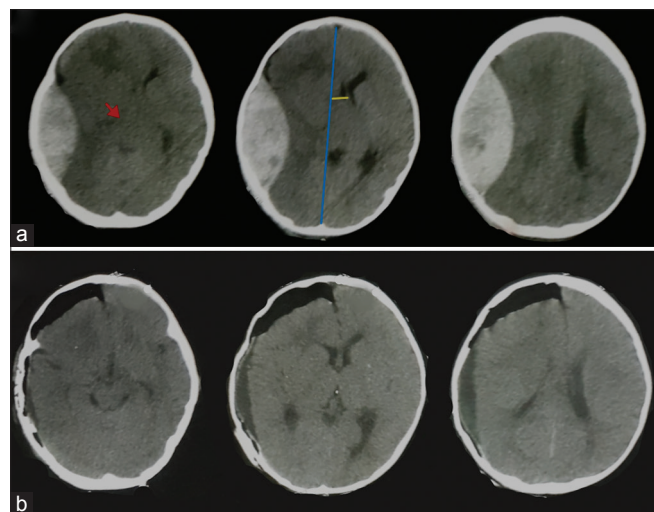

Figure 3: CT brain, axial cuts without contrast, (a) right temporoparietal epidural hematoma, red arrow; brainstem and cisternal compression, and blue and yellow lines highlight the midline shift. (b) Postoperative CT after hematoma evacuation, with relief of brainstem compression after surgery.

ml^3), there were eight cases had a preoperative hematoma volume >100 ml^3, seven out of eight developed postoperative infarction (P < 0.001).

Postoperatively, an ipsilateral cerebral infarction was identified in the form of hypodense areas along the distribution of PCA in seven children (25%).

The MLS was one of the important parameters that also indicated the occurrence of ipsilateral infarction, it was more than 10 mm in 14 cases (50%) and <10 mm in the other 14 children and similarly, all cases that developed infarction had MLS more than 10 mm (P = 0.001). The basal cisterns were compressed in 6/7 (85.7%) of patients who developed infarction (P = 0.004).

[Table 1] summarizes clinical and radiological data of patients.

DISCUSSION

EDH in children and especially in infants represents a rare and potentially life-threatening complication resulting from head injuries.[13,23] Unlike adults, EDHs in infants constitute a different clinical entity due to their nonspecific clinical presentation and the inability of infants to communicate;[13] however, postoperative infarction is uncommon sequelae.[25]

In our study, the most common mode of trauma in children was domestic fall from height in 27 cases (96.4%) which was concomitant with the same mode of trauma in many published series,[1,5,13,20,23] it has also been emphasized that even minor head injuries can lead to the development of an acute EDH in infants.[5,17] Being domestic minor incidents, the trauma might not raise the parent's concern immediately seeing that it is a mild hit, which, in turn, increases the time interval between the trauma and the specific management leading to higher probabilities of cerebral ischemia and worse outcome.

It was reported that temporoparietal and temporal regions are the most common locations of EDH in this age group.[9,20] Nevertheless, other studies lowered the rank of those regions in harboring the EDH.[2,8,21,23] This conflict may be attributed to the difference in the distribution of the abundant diploic veins and dural vascularity between infants and older children,[16,23] but in our series, the temporal region (temporal, temporoparietal, temporoparietal occipital, and frontotemporal) was involved in 14 cases (50%).

The importance of this temporal location, in particular, stems from its proximity to perimesencephalic cisterns and PCA branches, so that a hematoma in this site may have more possibilities to yield an infarction by distorting the cisterns with resultant compression of posterior circulation arteries against the tentorium by the herniating brain especially in children whose blood vessels are more elastic and more

Table 1: Summary of clinical data of patients.

	Infarction				*P* value
	No		Yes		
	Count	%	Count	%	
Sex					
Male	13	61.9	6	85.7	0.243
Female	8	38.1	1	14.3	
Age (Months)					
<12	8	38.1	3	42.9	0.823
12–24	13	61.9	4	57.1	
Mode of Trauma					
FFH	20	95.2	7	100.0	0.557
RTA	1	4.8	0	0.0	
Clinical Presentation					
DCL	7	33.3	5	71.4	0.078
Repeated vomiting	14	66.7	2	28.6	
Pediatric Glasgow Coma Scale					
<9	1	4.8	3	42.9	**0.036**
9–12	6	28.6	2	28.6	
13–15	14	66.7	2	28.6	
Neurological Deficits					
No	20	95.2	4	57.1	**0.023**
Seizures	1	4.8	1	14.3	
Weak left side	0	0.0	2	28.6	
Site of Hemorrhage					
T/TF/TP/TPO	9	42.9	5	71.4	0.190
Away from T	12	57.1	2	28.6	
Size of Hemorrhage (mm≥)					
<50	9	42.9	0	0.0	**<0.001**
50–100	11	52.4	0	0.0	
>100	1	4.8	7	100.0	
Preoperative Hemoglobin (g/dl)					
<7	2	9.5	3	42.9	0.093
7–10	9	42.9	3	42.9	
>10	10	47.6	1	14.3	
Time between Trauma and surgery (hours)					
<3	0	0.0	1	14.3	**0.004**
3–6	19	90.5	2	28.6	
>6	2	9.5	4	57.1	
Midline Shift (mm)					
No shift or<10	14	66.7	0	0.0	**0.001**
10–15	7	33.3	4	57.1	
>15	0	0.0	3	42.9	
Basal Cisterns					
Preserved	16	76.2	1	14.3	**0.004**
Compressed	5	23.8	6	85.7	

FFH: Fall from height, RTA: Road traffic accident, DCL: Disturbed conscious level, T: Temporal, TF: Tempro-frontal, TP: Temporoparietal, TPO: Temporoparietooccipital

liable to be kinked.[12,24] Compression of basal cisterns could be linked to postoperative infarction, it was compressed in 6/7 (85.7%) of patients who developed infarction (*P* =0.004).

The size of hematoma in relation to total blood volume in infants is the reason behind the apparent anemia in infants, it is estimated that children more than 3 months have 70 ml/kg as a total volume of blood.[11] The mean volume of hematoma was 72.75 ml³ and all the seven cases with hematoma volume >100 ml³ developed infarction, while only one patient with hematoma volume >100 ml³ developed infarction (*P* < 0.001).

Pasaoglu *et al.* reported that pallor and anemia occurred in nine out of ten infants in traumatic pediatric EDH series,[20] all 28 cases in our series had preoperative anemia (from 3.8 to 11.6 g/dl) and all of them received intraoperative packed Red Blood Cells. The presence of cephalohematoma can promote the anticipation of anemia but sometimes those patients have nothing but persistent crying and/or irritability.

The preoperative low hemoglobin was not linked to infarction development (*P* = 0.093), it was <7 g/dl in 3/7(42.7%) of children with infarction, and 1/7 (14.3%) of cases with infarction had preoperative hemoglobin >10 g/dl. The mean preoperative hemoglobin was 8.89 gm/dl (average from 3.9 to 11.8 g/dl) (*P* = 0.093), this means that even with children presented with low hemoglobin <7 g/dl, the on-table intraoperative correction by anesthesia early surgery through blood transfusion made those cases salvageable from infarction. [Figure 3] represents a case of 9-month-old child with preoperative hemoglobin 6 g/dl and salvaged from infarction.

MLS larger than 10 mm is usually associated with unfavorable outcomes due to cisternal compression with mechanical dragging and kinking of blood vessels,[14] all of our seven patients who developed infarction had MLS more than 10 mm, three of whom had MLS more than 15 with compressed basal cisterns; however, in one case with infarction, the MLS was 12 mm; yet, the cisterns were preserve (*P* = 0.001).

There was a relationship between the timing of surgery to head trauma and development of infarction (*P* = 0.004), about 90.5% of patients who did not develop infarction were operated on between 3 and 6 h from the time of trauma. Delay in the timing of surgery carries a great risk and to increase intracranial pressure (ICP), more than 50% of patients who developed infarction were operated on after 6 h from the time of trauma.

According to the ICP-volume curve, despite little addition of volume, the ICP remains the same until the point of decompensation where ICP rises incrementally.[3] At an extreme level of ICP, the cerebral blood flow is reduced due to a decrease in cerebral compliance and perfusion pressure with subsequent cerebral infarction.[3] The point of decompensation is unknown and variable in every case. Based on our series, the high compliance of the brain of children under the age of 2 years especially with open fontanelle could help to accommodate the large volume of blood till the decompensation point. Volume >100 ml³ and

delay in the time of surgery for more than 6 h with expected MLS >10 mm could be the factors that fasten the curve to reach the decompensation point and brain ischemic infarcts.

In our series, we tried to elucidate factors that could be linked to infarction from our tertiary-based practice. The time needed to reach the hospital is out of our hands especially in developing countries, but rapid correction of low hemoglobin and rapid surgical evacuation is the best to be done to salvage the brain. Up to 6 h could be the time limit after which infarction is inevitable.

Limitations

Being retrospective rather than a prospective study, the relatively small sample size is the main limitation of the study; however, the sample size was comparable to other pediatric EDH series[9,18-20] and our practice is in a high flow tertiary center.

CONCLUSION

Pediatric EDH is a surgical emergency that needs rapid intervention to achieve the best outcome. Parameter to predict the occurrence of ipsilateral infarction is GCS on admission, the presence of neurological deficit; the size of the hematoma, midline shift; compression of basal cisterns, and timing of surgery. Intraoperative rapid correction of low preoperative hemoglobin could salvage the brain from ischemic sequelae.

Declaration of patient consent

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

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Nil.

Conflicts of interest

There are no conflicts of interest.

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