Traumatic Epidural Hematomas in Children and Adolescents

Outcome Analysis in 39 Consecutive Unselected Cases

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Objective: Despite early diagnosis of traumatic epidural hematomas (EDHs) in children, mortality remained quite high in recent series. The aims of this analysis were to review the cause and outcome of pediatric EDH nowadays and to discuss outcome-related variables in a large consecutive series of surgically treated EDH in children.

Methods: This is a retrospective case series of 39 patients (27 males, 69%) with surgically treated EDH between June 1997 and February 2007. Patients' medical records, computed tomographic scans, and, if performed, magnetic resonance imagings were reviewed to define variables associated with outcome. Variables included in the analysis were age, associated severe extracranial injury, abnormal pupillary response, hematoma thickness, severity of head injury (Glasgow Coma Scale score ≤ 8), parenchymal brain injury, and diffuse axonal injury. Long-term follow-up (mean [SD], 51.3 [27] months) was available in 38 patients, and outcomes were classified as excellent (modified Rankin Scale score [mRS], 0; Glasgow Outcome Scale score, 5) and good (mRS scores, 1 and 2; Glasgow Outcome Scale score, 4).

Results: The mean (SD) age of the patients was 83.1 (59.9) months (range, 1–191 months). The mortality was zero, and the outcomes were excellent in 34 and good in 4 patients (one was lost to follow-up). Most of the injuries with EDH occurred in familial settings (23 cases), with falls being the most common mechanism of injury in 20 patients. Trauma was caused by traffic accidents in 14 cases (pedestrians hit by a motor vehicle, 7 cases; bicycle accidents, 5 cases; and motorbike and car accidents, 1 case each). One EDH occurred during delivery. The mean size of the EDH was 18.5 (12) mm (range, 5–40 mm). Three patients were referred with unilateral or bilateral dilated pupil(s). Except in 4 patients, all EDHs were associated with skull fracture(s) (90%). Computed tomography or magnetic resonance imaging revealed brain contusion in 13 patients, and 1 had diffuse axonal injury. None of the tested variables were found to have a prognostic relevance as tested by multivariate analysis (backward exclusion, Wald method).

Conclusions: Regardless of the EDH size, the clinical status of the patients, the abnormal pupillary findings, or the cause of injury, the outcome and prognosis of the patients with EDH are excellent.

Key Words: epidural hematoma, head injury, skull fracture, surgery, outcome

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Acute epidural hematomas (EDHs) in children and infants represent a potentially life-threatening condition after head injury. The reported incidence of EDH ranges between 1% and 6% after head trauma in hospitalized children.[1–6] However, some authors report an increased incidence of isolated EDH in recent years.[7] Early identification and adequate management depending on the patient's clinical condition and the size of EDH are prerequisites for good outcome. However, beside the presence of midline structure shift on head computed tomographic (CT) scan and clinical signs of uncal herniation, other factors, such as associated brain contusion, diffuse axonal injury (DAI), or extracranial injury, may determine the outcome of the children. Therefore, the aim of our study was to evaluate the cause and clinical course of children and adolescents with EDH in a large series of consecutive nonselected surgically treated cases.

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METHODS

Patient Population

Between June 1997 and February 2007, in 39 patients, a traumatic EDH was surgically treated. All the patients were included in a database at the time of treatment. Perioperative course, radiological findings, and outcome were evaluated retrospectively. Items included in the database were demographic features, cause of trauma, preoperative clinical status according to the Glasgow Coma Scale (GCS) score, signs of transtentorial herniation (unilateral or bilateral dilated pupil), isolated head injury or associated substantial extracranial injury, time to treatment (including the reason for delayed treatment, if performed), and the outcome according to the modified Rankin Scale (mRS) and Glasgow Outcome Scale (GOS). The outcome was classified as excellent (mRS score, 0; GOS score, 5), good (mRS score, 1.2; GOS score, 4), or adverse (mRS score ≥ 3; GOS score ≤ 3). Patients with penetrating head injuries were not included in this study.

Surgical Procedures and Imaging Studies

All the patients were treated according to a standard advanced trauma life support protocol if presented directly to the emergency department of our institution. Treatment included early intubation, sedation, and hemodynamic resuscitation. Indication for ventilation was neurological (GCS score ≤ 8), respiratory, or cardiovascular compromise. Trauma workup was initiated according to the clinical status and the mechanism of the trauma and usually included a head and body CT scan and abdominal ultrasound. In cases without CT of the cervical spine, a C-spine injury was ruled out by plain x-ray. After documentation of an EDH treatment, indication for surgery was a thickness of the hematoma of at least 1 cm (maximal thickness), dislocated skull fractures associated with EDH, or a documented increase of the hematoma size with or without clinical deterioration. Operative treatment of EDH was performed as a standardized procedure. After osteoplastic craniotomy, hematoma evacuation was performed. A thorough hemostasis was achieved, dural tenting sutures were placed, and skull fracture(s) was repaired. In patients with large and giant EDH intracranial pressure (ICP), measurement was performed during the postoperative course. Therefore, ICP probes were inserted via a small incision of the dura for subdural measurement. Any craniotomy performed more than 8 hours after injury was classified as "delayed." All the patients underwent either postoperative cranial CT or magnetic resonance imaging (MRI) to document adequate removal of the hematoma, trauma-associated brain contusion, or any complication related to the trauma or operative treatment. Magnetic resonance imaging was the preferred method of control imaging whenever DAI was suspected from the severity and mechanism of trauma. All the patients were treated at the pediatric intensive care unit until clinical stabilization. Cessation of ventilation and extubation were performed as soon as possible, depending on the postoperative ICP and associated extracranial injury. All the patients underwent EEG during their postoperative course. After the acute phase of the treatment, most of the patients were referred for rehabilitation.

Follow-Up and Statistical Analysis

Statistical analysis was performed using commercially available software (SPSS Version 11.0; SPSS Inc). The data of all parameters were given as mean (SD) except for the outcome scales. The patients' charts and the outpatients' documents were thoroughly reviewed for outcome assessment. All the patients had at least one follow-up during the postoperative course. In 30 of the 39 patients, a recent telephone interview was performed by 2 of the authors (R.G. and S.D.) to obtain information about the actual impairment. In the other patients, the outcome evaluation was based on the most recent follow-up visit. To define

TABLE 1. Summary of the Patients' Demographic Factors

No.	Age at Trauma, mo	Sex	Cause of Trauma	Pretreatment GCS Score	Pupillary Dilation	Occurrence of Associated Skull Fracture	Time to Evacuation, h	Operation With Delay
1	22	Male	Fall from balcony	8	No	Yes	2	No
2	1	Female	Fall from a caddy	15	No	Yes	96	Yes
3	129	Male	Stroller hit by a car	9	No	Yes	5	No
4	64	Female	Cycler hit by car	14	No	Yes	4	No
5	81	Female	Fall from a caddy	15	No	Yes	14	Yes
6	137	Male	Hit by horse shoe	14	No	Yes	3	No
7	36	Male	Fall from bunk bed	8	Yes	Yes	4	No
8	58	Female	Fall through window	8	No	Yes	4	No
9	175	Male	Motorbike accident	7	No	Yes	4	No
10	143	Male	Bicycle accident	4	Yes	Yes	5	No
11	50	Male	Hit by a bed	13	No	Yes	24	Yes
12	191	Male	Pedestrian hit by a tram	3	Yes	Yes	3	No
13	106	Male	Fall through window	15	No	Yes	216	Yes
14	156	Male	Bicycle accident	8	No	Yes	7	No
15	142	Male	Car accident	14	No	Yes	13	Yes
16	163	Female	Bicycle accident	13	No	Yes	3	No
17	51	Female	Pedestrian hit by a truck	13	No	Yes	7	No
18	18	Female	Fall from a couch	15	No	Yes	24	Yes
19	74	Male	Fall to bottom	14	No	No	48	Yes
20	152	Male	Bicycle accident	9	No	Yes	4	No
21	2	Male	Punished with something	7	No	Yes	4	No
22	14	Male	Fall from diaper changing table	12	No	No	14	Yes
23	76	Male	Fall from bunk bed	13	No	Yes	16	Yes
24	140	Male	Pedestrian hit by a car	13	No	Yes	4	No
25	164	Male	Fall to bottom	10	No	No	6	No
26	144	Male	Pedestrian hit by a bus	14	No	Yes	18	Yes
27	139	Female	Fall during running	13	No	Yes	18	Yes
28	130	Female	Fall from a roof	15	No	Yes	6	No
29	49	Male	Fall from a bunk bed	10	No	Yes	3	No
30	25	Male	Fall to bottom	12	No	Yes	5	No
31	18	Male	No obvious cause	15	No	Yes	24	Yes
32	1	Male	During delivery	14	No	Yes	5	No
33	87	Female	Fall from bunk bed	14	No	Yes	7	No
34	9	Male	Fall from diaper changing table	14	Yes	Yes	4.5	No
35	28	Male	Fall from bath tube	8	Yes	No	3	No
36	3	Male	Fall from bed	15	No	Yes	8	No
37	46	Female	Pedestrian hit by a car	15	No	Yes	120	Yes
38	65	Female	Fall from stairs	13	No	Yes	16	Yes
39	151	Female	Pedestrian hit by a car	14	No	Yes	5	No

variables associated with outcome, a binary logistic regression analysis with backward exclusion (Wald method) was performed to define the outcome-related prognostic influence of tested variables. Variables included in the analysis were age at trauma, isolated head injury, unilateral or bilateral dilated pupil(s), severe head injury (GCS score ≤ 8) before treatment, hematoma size, brain contusion injury, and time to operative evacuation. The significance level was $P < 0.05$.

RESULTS

Thirty-nine patients with EDH were surgically treated during the study period. Age ranged from 1 day to 16 years (83.1 [59.9] months). Five patients (12.8%) were younger than 1, 8 (20.5%) younger than 4, 11 (28.2%) between 4 and 10, and 15 (38.5%) older than 10 years. Twenty-seven patients (69.2%) were male, accounting for a male-to-female ratio of 2.25:1. Table 1 summarizes the patients' demographic data, the cause of trauma, pupillary abnormalities, and the occurrence of a skull fracture. None of the patients in this series died of EDH (0% mortality). After the acute treatment period, all the patients were either referred for rehabilitation or discharged home. Thirty-eight patients (97.4%) were available for follow-up, and only 1 patient was lost to long-term follow-up. The length of the follow-up was 51.3 (27) months (range, 2–108 months). Permanent trauma-related morbidity occurred in 2 patients. One patient developed a mild mental disturbance. In the other patient, the outcome was not directly associated to the EDH. A severe allergic reaction has led to prolonged ventilation and a toxic epidermal necrolysis resulting in skin necrosis. Another patient already experienced tuberous sclerosis before the trauma occurred, and the patient's general condition did not change after the treatment. In the fourth patient, a mental disturbance was also present before the trauma and apparently did not change afterward. The overall outcomes were excellent (GOS score, 5; mRS score, 0) in 34 patients (89.5%) and good (GOS score, 4; mRS score, 1.2) in 4 (10.5%) of the 38 patients.

Most traumas occurred in a familial environment (23 cases, 59%), with falls being the most frequent cause. Height was shorter than 1 m in 7 cases and taller than 1 m in 12 cases. A fall from a balcony or stairs was similarly frequent as the fall from a bunk bed. Traffic accidents were the cause of the EDH in 14 cases (pedestrians being hit by a motor vehicle in 7 cases, bicycle accidents in 5, and motorbike and car accident in 1 case each). In the remaining cases, the EDH was due to other mechanisms (hit by something). One case of EDH occurred during delivery.

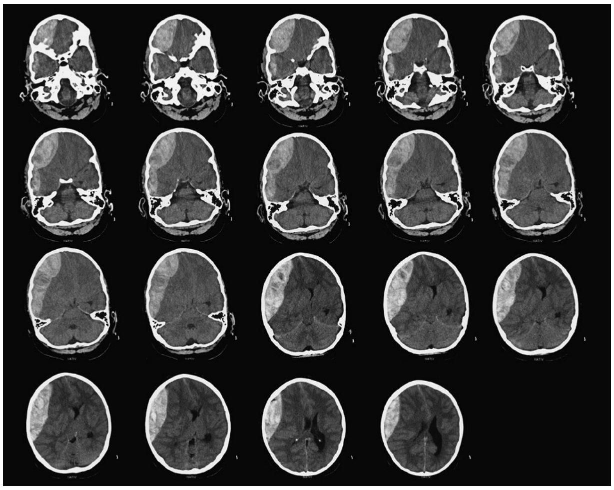

FIGURE 1. An illustrative case of a 12-year-old boy (patient 10) after a bicycle injury presenting with a GCS score of 4 and unilateral dilated pupil having an excellent outcome after surgical evacuation.

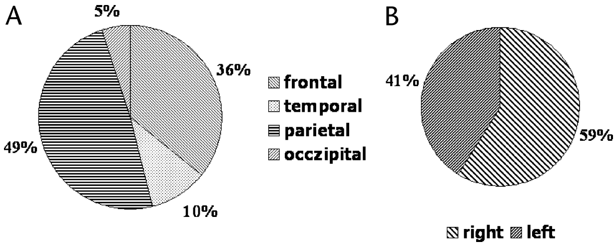

FIGURE 2. Location (A) and side (B) of all EDHs around the main portion of the hematoma.

The GCS score before hematoma evacuation ranged from 3 to 15 (11.8 [3.3]; range, 3–15). Nine patients (23.1%) sustained severe head injury (GCS score ≤ 8), 6 patients (15.4%) had a GCS score between 9 and 12, and in 24 patients (61.5%), the GCS score was 13 to 15 (Table 1). Three patients had unilateral fixed pupils, whereas the others had normal pupillary size and reactivity. Figure 1 shows a typical right frontal EDH in a 12-year-old boy after a bicycle crash presenting with a GCS score of 4 and a unilateral pupillary dilation.

The mean (SD) time to surgery was 19.9 (40.1) hours; however, 21 patients (53.8%) underwent surgical evacuation of the hematoma within 6 hours. Delayed surgery (more than 8 hours after trauma) was performed in 14 cases (35.9%). Reasons for this treatment delay were either delayed CT scan (4 cases; parents did not admit the child) or initial good clinical status and surveillance of the patients in peripheral hospitals with a hematoma size smaller than 1 cm (10 cases). In these patients, either an increase of hematoma size during CT control or a deterioration of their clinical status prompted surgical evacuation. The primary diagnostic modality was CT in 36 cases (92%) and MRI in 3 cases (8%). Hematoma location was parietal in 49%, frontal in 36%, temporal in 10%, and occipital in only 5% (Fig. 2). The right side was more frequently affected (59%) compared with the left side (41%). Radiological data on EDH are presented in Table 2. The mean (SD) size of the hematoma was 18.5 (12.0) mm (range, 5–40 mm), and 20 patients showed midline shift in initial imaging. Thirty-five patients (90%) had an associated skull fracture; in 13 patients (33.3%), a brain contusion was detected. Twenty patients underwent MRI after the treatment of the EDH, and only 1 patient showed signs of DAI. In 1 patient, a routine CT scan showed a recurrent EDH the day after initial surgery, and he underwent re-evacuation of the hematoma without further sequelae. Otherwise, no surgical complication occurred.

Logistic regression analysis did not prove one of the factors to be associated with patient outcome. Consistent with other results in this series, the outcome was highly independent of the clinical and radiological factors, which were found to be associated with outcome in other series.

DISCUSSION

Children sustaining cranial traumas associated with EDH represent a heterogeneous group with a variety of clinical outcomes. The approximated mortality is 5%,[1,8,9] although mortality in the quoted literature ranges from 0% to 12%[7,10–15] and was even higher in the pre-CT area.[5] Ben Abraham et al[10] found that children younger than 4 years had a 16.7% mortality compared

TABLE 2. Patient Radiographic Factors

No.	Size	Displacement of Midline Structures	Associated Brain Contusion	MRI During Follow-up	DAI	Outcome mRS Score	Outcome GOS Score
1	7	Yes	Yes	Yes	No	2	4
2	5	Yes	No	No	NA	0	5
3	8	No	Yes	Yes	No	0	4
4	6	No	Yes	No	NA	0	5
5	8	Yes	No	No	NA	0	5
6	5	No	Yes	Yes	No	0	5
7	25	Yes	No	No	No	0	5
8	40	Yes	Yes	Yes	Yes	1	4
9	40	Yes	Yes	Yes	No	0	5
10	40	Yes	No	Yes	No	0	5
11	32	Yes	No	No	NA	0	5
12	25	Yes	Yes	Yes	No	0	5
13	30	Yes	No	No	NA	0	5
14	25	Yes	Yes	Yes	No	0	5
15	11	Yes	No	Yes	No	0	5
16	10	Yes	No	Yes	No	0	5
17	8	No	No	No	NA	0	5
18	5	No	No	No	NA	0	5
19	22	Yes	No	No	NA	0	5
20	3	No	No	No	NA	0	5
21	10	Yes	Yes	Yes	No	1	4
22	30	Yes	No	No	NA	0	5
23	25	Yes	No	No	NA	0	5
24	10	Yes	No	No	NA	NA	NA
25	36	Yes	No	Yes	No	0	5
26	12	No	No	No	NA	0	5
27	9	Yes	Yes	Yes	No	0	5
28	15	Yes	No	Yes	No	0	5
29	25	Yes	Yes	Yes	No	0	5
30	25	Yes	No	No	NA	0	5
31	10	Yes	No	Yes	No	0	5
32	10	Yes	Yes	Yes	No	0	5
33	15	Yes	No	Yes	No	0	5
34	35	Yes	No	No	NA	0	5
35	22	Yes	No	No	NA	0	5
36	5	No	No	No	NA	0	5
37	NA	No	No	Yes	No	0	5
38	40	Yes	Yes	No	NA	0	5
39	15	Yes	No	Yes	No	0	5

NA indicates not applicable, which means that data could not been retrieved from the admission CT scan or patients' charts.

with 6.3% and 7.4% in children aged 4 to 10 years and older than 10 years, respectively. In the here presented series, mortality was zero and the overall outcome was excellent in most cases, which compares favorably with a smaller series of somewhat younger children conducted in Australia.[7] In our series, only 4 cases had good outcome, and the reasons for that were only indirectly related to the EDHs in 2 cases. A possible explanation for the overall very good outcome might be the advanced contemporary pediatric trauma care and urgent surgery in patients with clinical signs of uncal herniation.

Various factors, such as bradycardia,[11,12] GCS score[10,13–15] or other clinical scores,[11,12,16] seizures,[10] and focal neurological deficits,[10] have been demonstrated to predict outcome after treatment of EDH. Moreover, metabolic markers such as hyperglycemia and low potassium and pH levels were found to be associated with outcome[10] after traumatic EDH in children. Young age was associated with poor outcome in some series,[10,17,18] whereas others found older age to be associated with adverse outcome.[19] The mean age in this series was 83 months, and approximately one third of the patients were younger than 4 years. No association between age and outcome was found in this series. Findings of pupillary changes such as mydriasis and none reactivity to light were associated with a dismal prognosis in previous studies of EDH in infants.[10–12,20] However, some authors[13,15,19] could demonstrate a good outcome even when pupillary changes were present, as we did. The impact of skull fractures on outcome is controversial. The incidence of fractures in the presented series was 90%, which was more frequent compared with those in other series ranging from 48% to 80%[7,10,13–15] in children and 61% in neonates and infants.[12] As reported in previous studies, the relative risk for an EDH is increased fourfold in children with skull fractures.[21,22] Although a correlation of the number and volume of hemorrhagic lesions after brain injuries in children and adolescents with clinical outcome was reported,[23] this could not be confirmed even with a relatively high number of brain contusions (33.3%) in this and other series.[7,10] Interestingly, DAI was rarely associated with EDH according to our data, which has not been reported previously.

Browne and Lam[7] reported 85% of associated extracranial injury, which was far lower in the here presented data. Sixty percent of the patients were male, and this predominance is in accordance with previous reports.[2,3,7,10,12–15] As reported in other series,[10] the parietal region was most frequently involved; however, a high number of frontal EDH was found, too. Right side involvement was more common than left side involvement, which was mentioned previously.[12]

Consistently with other series,[7,10] a fall was the most common cause of trauma in our series. Traditionally, an EDH has been considered to result from substantial head injury only; however, it has to be emphasized that even a fall from a minor height[15,24–26] (lower than 1 m) can cause EDH and may carry a worse prognosis.[11] Ben Abraham et al[10] found that the mechanism of injury differed with age, with falls being much more common in children younger than 5 years and motor vehicle accidents in children older than 5 years. Noteworthy is that approximately 50% of the EDHs were related to accidents at home or within familial environment. Only roughly one third of the accidents were traffic related. Pedestrians being hit by motor vehicles were slightly more common compared with bicycle injuries in this series, whereas bicycle accidents were more frequent in other series.[10]

The criteria for selecting cases for conservative or surgical treatment remained controversial.[27–31] Chen et al[28] suggested that a hematoma volume larger than 30 mL with a thickness of more than 15 mm and a midline shift more than 5 mm constitutes a strong indication for surgical treatment. Similarly, Bejjani et al[27] found that the most important radiographic parameters dictating surgical evacuation were maximum diameter of hematoma of more than 18 mm and midline shift of more than 4 mm. In contrast, small EDHs with a thickness less than 1 cm and an anteroposterior diameter on CT of less than 3 cm with no midline shift in an asymptomatic patient might favor conservative treatment.[8,11,30] Our policy for treatment of EDH is somewhat different. Only patients with EDHs less than 10 mm and no focal deficits were treated conservatively and followed up closely, but if any deterioration occurred and/ or an increase in the size of the hematoma was seen, we decided to perform a surgical evacuation. Of course, there is a degree of subjectivity in the decision of the attending neurosurgeon when or when not to operate a child with EDH. Sullivan et al found that in patients with EDH and conservative management, an early (<36 hours) increase in hematoma size occurred in 23% of patients. One of the 13 patients with conservatively managed EDH underwent surgical evacuation 120 hours after trauma because of clinical deterioration in another series.[31] Our opinion is that the risks of surgery and anesthesia are low; therefore, this treatment may prevent other complications, such as calcification of the EDH.[32]

The mean time to surgical intervention was 19.9 hours, which compares favorably with other studies,[10] but more than 50% of the patients were treated within 6 hours. However, unspecific signs and symptoms after trauma, especially in younger patients, remain a clinical dilemma leading to the assumption of a medical rather than a surgical problem, and this may lead to a delay in diagnosis and treatment. This has also been highlighted by other groups.[7,33–36]

Although the patients were entered into a database at the time of admission, the retrospective evaluation of clinical and radiological data is a clear limitation of this study. However, the relatively large number of patients included in this series with a long-term follow-up and a thorough statistical analysis may outweigh this shortcoming. Until proven by prospective assessment, the here presented very good outcome may be kept in mind if children with extensive EDH and clinical signs of uncal herniation are seen in the emergency department and if any effort must be made to perform urgent surgical evacuation.

CONCLUSIONS

Pediatric EDH can be managed with excellent outcome even in children with low GCS scores, abnormal pupillary reaction, and large hematoma size. These cases should be treated surgically without any delay. Most of the patients in this series sustained head injury in a familial environment, and the EDHs were associated with skull fractures in 90% of the cases. This should be considered during admission of children in the emergency department.

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