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ORIGINAL PAPER

Supratentorial epidural hematoma of traumatic etiology in infants

A. V. Ciurea · E. Z. Kapsalaki · T. C. Coman · J. L. Roberts · J. S. Robinson III · A. Tascu · F. Brehar · K. N. Fountas

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Abstract
Introduction and background Traumatic epidural hematoma (EDH) represents a rare head injury complication in infants. Its diagnosis can be quite challenging because its clinical presentation is usually subtle and nonspecific. In our current communication, we present our data regarding the presentation of infants with EDH, their management, and their long-term outcome.
Materials and methods In a retrospective study, the hospital and outpatient clinic charts and imaging studies (head CT and skull X-rays) of 31 infants with pure, supratentorial EDH of traumatic origin were meticulously reviewed. Children Coma Scale score and Trauma Infant Neurologic Score (TINS) were also reviewed. The most common presenting symptom was irritability, which occurred in 18/31 (58.1%) of our patients. Pallor (in 30/31 patients) and cephalhematoma (in 21/31 patients) were the most commonly occurring clinical signs upon admission; both signs represent signs of significant clinical importance. Surgical evacuation via a craniotomy was required in 24/31 of our patients, while 7/31 patients were managed conservatively. The mortality rate in our series was 6.5% (2/31 patients), and our long-term morbidity rate was 3.2% (1/31 patients).
Conclusions EDH in infants represents a life-threatening complication of head injury, which requires early identification and prompt surgical or conservative management depending on the patient's clinical condition, size of EDH, and presence of midline structure shift on head CT scan. Mortality and long-term morbidity are low with early diagnosis and prompt treatment.

Keywords Cephalhematoma · Epidural hematoma · Infant · Outcome · Pallor · Traumatic Infant Neurologic Score (TINS)

Introduction

Traumatic epidural hematoma (EDH) constitutes a rare clinicopathological entity in children. It has been estimated that EDH represents 2–3% of all head injuries in the pediatric population, and the incidence of EDH is even rarer among infants under the age of 12 months [1–5]. However, the specific characteristics of this group of patients and the subtle presenting symptomatology of EDH make it difficult to diagnose this and often challenging to manage. Furthermore, the criteria for utilizing surgical evacuation vs conservative management have remained ill-defined. Thus, the lack of any guidelines regarding the appropriate management of EDH in pediatric patients and particularly in infants makes the management of this specific group of patients all the more complicated. The reported mortality rates associated with EDH in infants and children vary significantly among various clinical series [6–10], and this wide variation is indicative of the

A. V. Ciurea · T. C. Coman · A. Tascu · F. Brehar
Department of Neurosurgery,
Clinics and Hospital "Bagdasar-Arseni",
Bucharest, Romania

E. Z. Kapsalaki
Department of Neuroradiology,
Medical Center of Central Georgia,
Macon, GA, USA

J. L. Roberts · J. S. Robinson III · K. N. Fountas
Department of Neurosurgery, Medical Center of Central Georgia,
Macon, GA, USA

K. N. Fountas (✉)
840 Pine St. Suite 880, Macon, GA 31201, USA
e-mail: knfountasmd@excite.com

regrettable absence of a widely accepted protocol for managing these patients.

In our current communication, we present our data from a series of infants diagnosed with traumatic EDH and managed in our institutions; emphasis had been given to their presenting symptoms and signs, their diagnostic significance, and also to the long-term outcome of these patients.

Materials and methods

Thirty-eight infants (age <2 months) admitted to our departments during a 15-year period (1990–2004) with the diagnosis of traumatic supratentorial EDH were examined in our retrospective study. The study was approved by the Institutional Review Board of both institutions, and data analysis was performed in accordance to the Health Insurance Portability and Accountability Act regulations. All patients' hospital and outpatient clinic charts and radiographic studies were meticulously reviewed. Patients with spontaneous EDH or patients with EDH of unknown etiology, as well as patients with infratentorial EDH, were excluded from our current study. Furthermore, patients with "double" epidural hematomas were also excluded from our study. Additionally, seven patients were lost to follow-up, decreasing our study population to 31 patients.

A meticulous physical examination, with an emphasis on neurological function, was performed upon admission. Each infant's admitting laboratory workup included measurements of complete blood count, serum electrolytes, blood urea nitrogen, creatinine, serum glucose, and prothrombin and partial thromboplastin times. All patients underwent a head CT scan, and plain skull X-rays were obtained for 17/31 (54.8%) patients, primarily during the initial phase of the study. Long bone radiographic survey and ophthalmologic examination, including but not limited to fundoscopic examination, were obtained whenever suspicion of child abuse was raised.

Patient management was either surgical or conservative based on the infant's clinical condition, Children Coma Scale (CCS) score, Beni-Adani score, evidence of midline shift on the initial head CT scan, and size of the EDH. Conservative management consisted of close observation in either a neonatal or a pediatric intensive care environment, with heart rate, respiratory rate, and oxygen saturation monitoring in addition to frequent neurological clinical examinations and serial head CT scans (initially at admission, and then at 12, 24, 48, and 72 h unless neurological changes dictated otherwise). Surgical management consisted of craniotomy under general endotracheal anesthesia and removal of the underlying hematoma.

The follow-up time in our series ranged between 12 and 60 months (mean 36.8 months, median 24 months). The patient's follow-up included clinical examination with detailed neurological examination, imaging studies (head CT in all patients), electrophysiologic studies (EEG) in 12/31 (38.7%) patients, and neuropsychological evaluation in 6/31 (19.4%) patients. The Glasgow Outcome Scale (GOS) was utilized for evaluating the outcomes in our series.

Results

The ages of patients ranged between 1 day and 12 months, with a mean age of 6.5 months and a median of 10 months. There were 18 males and 13 females. In regard to the lateralization of the hematoma in our study, 21/31 (67.7%) were located on the right side, and the remaining 32.3% were located on the left side, while the temporo-parietal area was the most common anatomical location of the hematoma (Table 1).

The mechanisms of injury in our series were: fall from height in 15 cases (48.4%), proven child abuse in 7 cases (22.6%), motor vehicle accidents in 5 cases (16.1%), obstetric maneuver during delivery in 3 cases (9.7%), and domestic accident in 1 case (3.2%).

The admitting CCS scores of our patients are summarized in Table 2. Our Trauma Infant Neurologic Scores (TINS) are summarized in Tables 3 and 4. It is interesting to note that both of our patients who died had a TINS score of 10 upon their admission. Our patients' presenting symptoms and clinical signs are presented in Table 5. The most common symptom in our series was irritability (agitation and persistent, unusual crying), which occurred in 18/31 (58.1%) patients. It is interesting to note once again that in 30/31 (96.8%) patients, remarkable pallor was clinically evident upon their admission, while in 21/31 (67.7%) patients, a cephalhematoma was evident.

The radiographic studies of our patients revealed an associated cranial fracture in 19/31 (61.3%) patients. The size of the EDH was found to be more than 2 cm in 23/31 (74.2%) patients, between 1 and 2 cm in 3/31 (9.7%), while in 5/31 (16.1%), EDH was less than 1 cm in its largest diameter.

Table 1 Anatomic location of the EDH in our series in the order of decreasing frequency

Number of patients	Anatomic location of EDH
14	Temporo-parietal
7	Parietal
6	Temporal
2	Frontal
2	Fronto-temporo-parietal

Table 2 Summary of CCS admitting scores in our series

Admitting CCS score	Number of patients
13–15	12
9–12	13
4–8	6

Emergent surgical evacuation (Fig. 1a,b) under general endotracheal anesthesia was performed in 24/31 (77.4%) of our patients, while the remaining 7/31 (22.6%) were conservatively treated. The length of hospitalization in our series ranged between 3 and 12 days (mean 4.2 days, median 5 days). The outcomes in the surgical group at discharge were as follows: two patients had a GOS score 1, four patients had a GOS score 4, and 18 patients had a GOS score 5. Respectively, the outcomes for the conservative group were: one patient had a GOS score of 4, and six patients had a GOS score of 5. At 6 months after treatment, three patients in the surgical group had a GOS score of 4, while 19 patients had a GOS score of 5. In the conservative group, one patient maintained a GOS score of 4 and six patients a GOS score of 5. At 12 months after treatment, all 22 patients in the surgical group had a GOS of score 5, while in the conservative group, all seven patients had a GOS score of 5. No outcome changes were observed at 24 months after treatment. No long-term posttraumatic sequelae were encountered except in three cases (two were surgically treated and one conservatively) where the patients suffered rare episodes of seizures. One of these patients has remained on anticonvulsant medications with excellent control of his seizures, and the other two are seizure-free with no medications.

Table 4 Our data regarding TINS admitting scores as proposed by Beni-Adani

Trauma Infant Neurologic Score (TINS) as proposed by Beni-Adani	Number of patients in our series
10	2
9	1
8	5
6	1
5	4
1–4	18

Neuropsychological evaluation data were available in six of our patients. Analysis of these data demonstrated normal psychomotor development in all these children.

Discussion

It is well known that acute epidural hematomas in children, and especially in infants, represent a quite rare and potentially life-threatening complication resulting from

Table 3 Our data regarding TINS admitting scores as proposed by Beni-Adani

Grading parameter	TINS Score as proposed by Beni-Adani	Number of patients in our series
Trauma mechanism		
A. Unknown	0	0
B. Minor injury (fall ≤1 m, mild head blow)	1	11
C. Major injury (fall >1 m, MVC, abuse)	2	20
Intubated upon admission		
A. Yes	1	7
B. No	0	24
Neurological examination		
Alertness		
A. Full	0	14
B. Sleepy but arousable	1	11
C. Unconscious	2	6
Pupils		
A. Normal	0	24
B. Anisocoria or nonreactive	1	5
C. Mydriasis and nonreactive	2	2
Motor deficit		
A. None	0	21
B. Lateralizing sign or weakness	1	7
C. No movement	2	3
Subgaleal hematoma		
A. Yes	1	21
B. No	0	10

Table 5 Frequency of presenting symptoms and clinical signs in our series

Presenting symptom and clinical sign	Number of patients	Percentage in our series
Pallor	30	96.8
Cephalhematoma	21	67.7
Irritability (agitation, crying)	18	58.1
Somnolence	11	35.5
Emesis	11	35.5
Bulging of anterior fontanel	10	32.3
Hemiparesis	7	22.6
Bradycardia	7	22.6
Coma	6	19.4
Seizures	5	16.1
Unilateral mydriasis	5	16.1
Unilateral nonreactive pupil	4	12.9
Fever	3	9.7
Hemorrhagic shock	3	9.7
Bilateral mydriasis	2	6.5
Bilaterally nonreactive pupil	2	6.5

head injuries [11–13]. Furthermore, epidural hematomas in infants constitute a different clinical entity than the ones in adults due to their nonspecific clinical presentation and the inability of infants to communicate. The number of published clinical series reporting on the outcome of infants sustaining acute epidural hematomas is limited due to the infrequent occurrences of this entity [14]. Various outcome predictive factors have been identified in these previous studies; however, their findings are occasionally contradictory [11–13].

The most common mechanism of injury in infants, in our series, was domestic fall from height in 48.4% of our cases. Our finding is in agreement with previous reports stating that this is the predominant cause of such injuries [11–15]. Beni-Adani et al. [14], in their infantile series, reported that in 63.6% of their cases, fall from height was responsible for the development of an acute epidural hematoma. Similarly, Pasaoglu et al. [12] found that fall was the most common underlying mechanism in 63% of their pediatric cases, and Ersahin et al. [13] identified fall as the most common mechanism of injury in 62% of their pediatric cases. Contrariwise, Rocchi et al. found that traffic-related accidents were the most common cause of EDH in their series; this finding might be explained by the fact that they reported on children and not solely on infants [11]. It has been demonstrated since before that falls represent the most common cause of EDH in infants and children up to 5 years old [15]. It has also been emphasized that even minor head injuries can lead to the development of an acute EDH in infants [14, 16]; this is despite of the fact that falls from more than 1 m height carry worse prognoses [14].

A male predominance has been identified among patients suffering acute EDH; in previous pediatric series, male to female ratios ranged from 2.3 to 2.8 [11–13, 15]. However, this male predominance was only slight (male/female ratio only 1.3) in our series.

In regard to the presenting symptomatology of infants, our findings confirm those of previous studies stating that nonspecific irritability or persistent crying represent the most common, and frequently the only, symptom of an acute EDH. Because these symptoms are so general, accurate clinical diagnosis is often difficult and requires the employment of a head CT scan even in cases of the slightest suspicion of EDH. The appearance of moderate pallor in 96.8% of our patients upon admission was a characteristic sign of major diagnostic significance. Similarly, Pasaoglu et al. [12] reported that pallor and anemia occurred in 90% of their infantile cases. Anemia, associated with pallor, has been identified since before as an important laboratory finding in infants with acute EDH [2, 7, 13, 17, 18]. Cephalhematoma was another common clinical sign, which occurred in 67.7% of our cases. Likewise, Beni-Adani et al. reported the existence of cephalhematoma in the vast majority of their patients [14]. It is interesting to

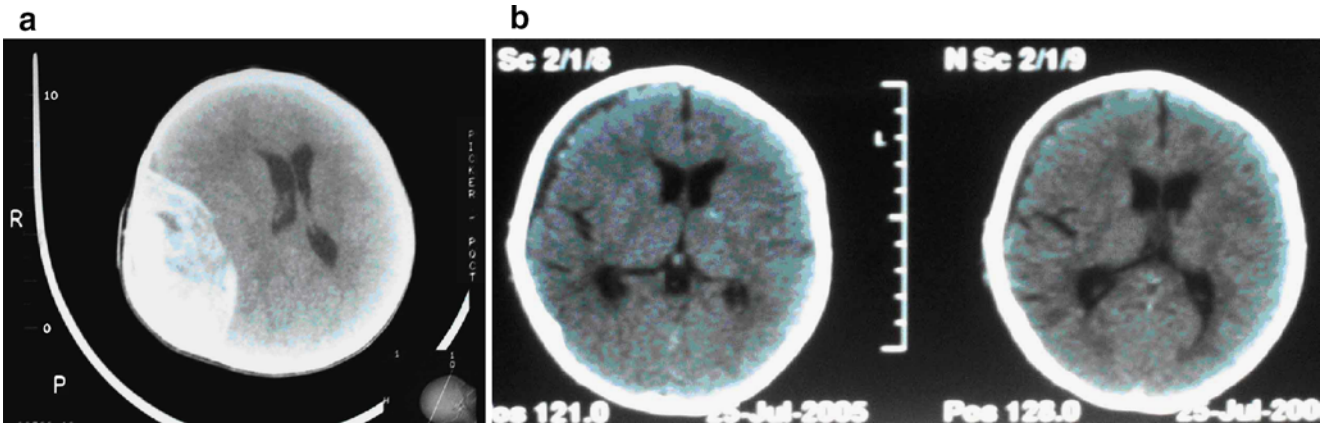

Fig. 1 **a**, **b** Preoperative and postoperative head CT scans in a 5-month-old infant with EDH

note that we did not observe lucid intervals in any of our patients. Pasaoglu et al. [12], however, reported that 32% of their pediatric patients presented with a typical lucid interval. Ersahin et al. [13] reported that 24% of their patients who presented with a lucid interval died, while their mortality rate among patients presenting without a lucid interval was significantly lower. Past studies demonstrate that the presence of a lucid interval can easily mislead or delay the accurate diagnosis and the prompt management of an underlying EDH [14, 19].

Pupillary changes, such as mydriasis and nonreactivity to light, although uncommon in our series (5/31 patients, 16.1%), occurred in all of our patients with dismal prognoses. Similarly, in Beni-Adani's series [14], the only infant who died presented with unilaterally nonreactive pupils, whereas all of the patients with normal pupillary size and light reactivity had excellent outcomes. Ersahin et al. [13] found that half of their patients presenting with bilateral mydriasis had poor outcomes. Likewise, Abraham et al. [15] found that pupil abnormalities upon admission were significantly associated with poor outcomes. Pasaoglu et al. [12] and Rocchi et al. [11] in their pediatric series reported higher incidence of pupillary abnormalities in their patients, though their findings did not seem to have an effect on their patients' final outcome.

Bradycardia upon admission occurred in 7/31 (22.5%) of our patients. It is interesting to note that 2/7 (28.6%) of these patients died, confirming the findings of a previous study that identified bradycardia as a very dismal prognostic factor in infants and children with acute EDH [14].

Various clinical examination grading systems have been proposed for the evaluation of infants [11–14, 20]. Ersahin et al. [13] and Pasaoglu et al. [12] concluded in their studies that the Glasgow Coma Scale (GCS) scoring system accurately assessed neurological condition even in infants and was associated with outcome in a statistically significant fashion. Similarly, Rocchi et al. [11] found that preoperative neurological status examined either by GCS or CCS had a significant impact on outcome. In their study, Beni-Adani et al. stated that the widely used CCS system included parameters which were difficult to interpret and score, and they therefore suggested a new scoring system (TINS) that included more objective parameters [14]. We utilized their system in our study because we share their concerns regarding the applicability of the GCS and the CCS grading system for evaluating infants. We found high TINS scores (10) in both of our patients who eventually died. Unfortunately, the limited number of our cases makes the extraction of any statistically meaningful conclusions regarding the outcome predictive value of TINS scoring scale impossible.

The temporo-parietal area was the most common anatomical location of EDH in our study. Our findings demonstrated that anatomical location was not associated with outcome. Similarly, Ersahin et al. [13] and Pasaoglu et al. [12] reported that temporo-parietal and temporal regions were the most common locations in their series; again, no relationship between anatomical location of EDH and outcome was established. Previous investigators, however, have postulated that temporal location might contribute to increased mortality due to predisposition to uncal herniation [21–24]. It is interesting to note that Rocchi et al. [11] found a low incidence of temporal hematomas in their series; their explanation mechanism for this finding was that in infants and young children, the middle meningeal artery is not indented in the temporal bone, so it is less vulnerable to injury. In addition, the prevalent diploic and dural vascularization of skull bones in infants and children can explain the nontypical anatomical locations of EDH [11].

In regard to the identification of an associated skull fracture by CT scan, this occurred in 19/31 (61.3%) of our cases. Ersahin et al. [13] found that 79% of their patients sustained a skull fracture, while the respective percentage in the series of Pasaoglu et al. [12] was 60%. Rocchi et al. [11] reported an even lower incidence of skull fractures (54.2%) in their study. The possibility of dural detachment from the overlying inner table as a result of the different elasticity coefficients between dura and bone might well explain the development of an acute EDH without a fracture in infants and young children [11, 25]. Previous studies have shown that the relative risk for intracranial injury is increased almost fourfold in the presence of a skull fracture [26, 27]. However, the absence of a skull fracture cannot rule out an EDH or any other intracranial injury [26]. Furthermore, fractures may not be recognized radiologically due to the thinness of the skull in infants [12].

The treatment of choice in the majority of acute traumatic EDHs remains to be surgical evacuation via a flap craniotomy [11–14]. In our series, 77.4% of the cases were surgically evacuated, while only 22.6% were treated conservatively. However, it must be emphasized that our centers are tertiary neurosurgical centers, so our population might represent a somewhat preselected one, consisting of patients referred to our facilities due to their larger sized hematomas or their poor clinical condition. The criteria for selecting patients for conservative vs surgical treatment have remained controversial [28–32]. Chen et al. suggested that a hematoma volume larger than 30 ml, with thickness of more than 15 mm, and a midline shift more than 5 mm constitute strong indications for surgical evacuation [29]. Similarly, Bejjani et al. [28] demonstrated that the most important radiographic parameters dictating surgical evacuation were maximum diameter of hematoma more than 18 mm and midline shift more than 4 mm. On the other hand, small epidural hematomas with thickness less than 1

cm and antero-posterior diameter on CT of less than 3 cm with no midline shift in an asymptomatic patient might favor conservative treatment [14]. Our findings concurred with the suggested treatment methods of these previous studies.

The surgical technique for treating EDH is very standardized and straightforward. However, neurosurgical expertise improves outcome, a supposition that has been demonstrated since before [33]. Special considerations, such as maintaining adequate cerebral perfusion pressure and normothermia, need to be appropriately addressed and accounted for during surgery. The risk of hemorrhagic shock even with minimal blood loss in infants cannot be overemphasized. The presence of a specialized pediatric anesthesiology team and availability of blood products for intraoperative transfusion are parameters of paramount importance in these cases. Our (6.5%) mortality rate is similar to that reported by Beni-Adani et al. [14] (9.1%) in their infantile series. Rocchi et al. [11] reported a mortality rate of 5.5% in pediatric patients having solely epidural hematomas. Similarly, Ersahin et al. [13] reported mortality of 6% in their pediatric series. Pasaoglu et al. [12], in their series, reported mortality rate of 12% in patients with pure epidural hematomas. However, a large number of their patients were treated in the pre-CT era, a fact that could significantly delay the diagnosis and the prompt management of EDH [12]. Our long-term morbidity rate was only 3.2% (one patient with chronic seizures, well controlled with medications). The limited data of our study regarding the neuropsychological development of these infants revealed no long-term consequences. Nevertheless, the psychomotor and cognitive development of infants sustaining EDH is an area that requires further study.

Conclusion

EDH in infants represents a rare but life-threatening complication as a result of head injury. Fall from height is the most common underlying cause of EDH in infants. Although EDH in infants is usually presented nonspecifically and can be associated only with subtle symptoms and clinical signs, clinicians should be especially alarmed by the presence of moderate pallor and/or cephalhematoma. Beni-Adani's grading system was more easily applicable in our series and might be more accurate than the CCS grading system in infants. However, large-scale, prospective, comparative clinical studies are necessary for establishing its accuracy and its outcome predictive value. Head CT scan remains the method of choice in establishing the diagnosis of an EDH. The patients' neurological condition, the size of the EDH, and the presence of midline shift on head CT scans are the most commonly employed criteria for making a decision between surgical or conservative treatment.

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