

Surgical options for treatment of traumatic subdural hematomas in children younger than 2 years of age

Clinical article

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Object. Subdural hematoma (SDH) is the most common finding on cranial CT in pediatric victims of abusive head trauma (AHT). The hematomas are commonly bilateral and sometimes associated with interhemispheric hyperdensity and/or convexity hemorrhages. There is no consensus regarding the best surgical treatment in such cases nor are there standardized surgical protocols. The authors report their experience and discuss the routine surgical options in the management of traumatic SDH at a Level 1 Pediatric Trauma Center.

Methods. In this paper, the authors describe a cross-sectional study with consecutive revision of data described in the medical records of Hôpital Universitaire Necker–Enfants Malades between January 2008 and January 2013. During this period, all children younger than 2 years of age who were admitted with a traumatic SDH identified on CT scans were included in this study.

Results. One hundred eighty-four children who had SDH and were younger than 2 years of age were included. Their median age was 5.8 months (range 5 days–23 months), and 70% of the children were male. On admission CT scans, the SDH was bilateral in 52% of cases and homogeneously hypodense in 77%. Neurosurgical treatment was undertaken in 111 children (60%) with an admission Glasgow Coma Scale score of 12 or less, bulging fontanel, or other signs suggestive of intracranial hypertension. The first surgical option was craniotomy in 1.8% (2) of these 111 cases, decompressive craniectomy in 1.8% (2), transcutaneous subdural puncture in 15% (17), external subdural drainage in 16% (18), subdural-subgaleal shunt placement in 17% (19), and subdural-peritoneal shunt placement in 48% (53). In 82% of the children initially treated with transcutaneous subdural puncture and in 50% of those treated with external subdural drainage, increase or persistence of the SDH, CSF or skin infection, or shunt system malfunction was observed and further surgical intervention was required. There was a 26% rate of complications in patients initially treated with a subdural-peritoneal shunt. Although 52% of the patients had bilateral SDH, bilateral drainage was only required in 9.4%.

Conclusions. The choice of treatment should be determined by the clinical and radiological characteristics of the individual case. Although effective on an emergency basis, subdural puncture and external subdural drainage are frequently insufficient to obtain complete resolution of SDH, and temporary placement of a subdural-peritoneal shunt is needed in most cases.

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KEY WORDS • brain injury • craniocerebral trauma • surgical procedures • shaken baby syndrome • subdural hematoma • abusive head trauma

THE most common findings on cranial CT in pediatric victims of abusive head trauma (AHT) are subdural hematomas (SDHs), present in more than 70% of cases.^{2,3,8,14,16,23} The SDHs are commonly bilateral and sometimes associated with interhemispheric hyperdensity and/or convexity hemorrhages.^{3,7,8,30} The management op-

tions remain controversial and range from conservative clinical surveillance (nonsurgical management) to subdural punctures, external subdural drainage, subcutaneous reservoirs, subdural-subgaleal shunts, subdural-peritoneal shunts, craniotomy, and sometimes, decompressive craniectomy.^{17,18,31}

To the best of our knowledge, a protocol to manage these children with traumatic SDH (due to AHT) is rarely described and surgical treatment is not standardized. In this paper we describe the experience of surgical manage-

Abbreviations used in this paper: AHT = abusive head trauma; GCS = Glasgow Coma Scale; ICH = intracranial hypertension; SDH = subdural hematoma; TCD = transcranial Doppler.

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ment of traumatic SDH in children less than 2 years of age in a Level 1 Pediatric Trauma Center in Paris, France.

Methods

This single-center study was performed in agreement with French legal requirements (institutional review board consultation, no informed consent required, anonymous computer data bank analysis) and in accordance with legal and ethical guidelines for research involving human beings, respecting and ensuring the confidentiality of identity.

Study Design and Sample

Cross-sectional study with a consecutive revision of data described in medical records between January 2008 and January 2013 (5 years), of children hospitalized in a Reference Level 1 Pediatric Trauma Center (Hôpital Universitaire Necker–Enfants Malades, Paris, France). The inclusion criteria were as follows: evidence of traumatic SDH on admission CT scans; absence of metabolic, blood coagulation, or infectious diseases; and absence of reported witnessed accident (such as fall from heights) or traffic-related accident at hospital admission.

Children were considered at risk for AHT when a clear history of trauma was not related by parents or caregivers. After in-hospital stabilization in the intensive care unit—including seizure control or at least systematic prophylaxis as well as endotracheal intubation and placement of central venous and arterial line catheters for invasive monitoring, when needed—further explorations included transcranial Doppler (TCD) ultrasonography, electroencephalography, whole-body skeletal radiography, and ophthalmological examination. A complete biological screening eliminated a coexisting disease in all cases.

The following medical information was systematically recorded: patient age, sex, and initial clinical findings (initial Glasgow Coma Scale [GCS] score, seizures, signs of intracranial hypertension [ICH], neurological deficits, associated bruises or fractures, and ophthalmological lesions); and a description of the SDH and associated lesions on cranial CT. The SDHs were classified as small (< 5 mm in diameter), medium (5–10 mm in diameter), and large (> 10 mm in diameter) when measured in the axial CT image depicting the thickest part of the lesion.¹⁷

Surgical Treatment

Neurosurgical treatment indications were based on previously reported criteria. Emergency surgical treatment was considered in patients with an admission GCS score of 12 or lower, bulging fontanels, or other signs suggestive of ICH.^{17,20,29,31} Large SDHs (those with a diameter \geq 10 mm) with associated clinical criteria were also considered as primary surgical indications.^{17,20,29,31} Surgical treatment options were left to the discretion of the pediatric neurosurgeon and included the following.

Isolated or Serial Transcutaneous Subdural Punctures. Transfontanel puncture is performed in the external angle of the anterior fontanel.

External Subdural Drainage. An incision is made near

the external angle of the anterior fontanel. After coagulation and dural puncture, a catheter was introduced into the subdural space and then tunneled under the scalp and connected to the external drainage.

Placement of a Subdural-Subgaleal Shunt. An incision is made near the external angle of the anterior fontanel. Subgaleal dissection is performed, separating the galea from the periosteum, and a 3-cm catheter is introduced into the subgaleal space. After coagulation and dural puncture, the proximal end of the catheter is introduced into the subdural space. The distal end is then attached to the scalp. For both subdural-subgaleal and subdural-peritoneal shunts, a valveless system was used.

Placement of a Subdural-Peritoneal Shunt. An incision is made near the coronal suture and a contralateral auricular incision is also performed. A mini-laparotomy is performed for the tunneling of the distal catheter. A bur hole is made for osseous and dural exposure. After coagulation and opening of the dura, an angled 3-cm catheter is introduced into the subdural space. This proximal catheter is then connected to the distal catheter and fixed to the periosteum. The distal catheter is introduced under direct vision into the peritoneal cavity. The musculoaponeurotic, subcutaneous, and cutaneous layers are then closed.

Other Surgical Procedures. Craniotomy and decompressive craniectomy are not generally used on victims of AHT and are reserved only for cases of acute SDH with mass effect and/or midline shift. Classically, craniotomies are performed by means of a frontotemporoparietal incision on the side of the hematoma, with opening of the bone and dura and drainage of the hematoma. When decompressive craniectomy was required, we opened the bone and dura further for better drainage of the hematoma and for decompression. Dural closure was performed using a galeal graft to prevent strain on the adjacent brain, leaving the patient without the bone flap.

Follow-Up and Complications

Data from surgical follow-up and details of any complications (including shunt infection, failure, or dysfunction) were recorded for at least 6 months after surgery.

Data Analysis

The results are presented as descriptive statistics. Epi Info version 7, public domain statistical software for epidemiology developed by the US Centers for Disease Control and Prevention (CDC), was used for elaboration and analysis of the database.

Results

One hundred eighty-four children younger than 2 years were hospitalized between January 2008 and January 2013 in the pediatric neurosurgical intensive care unit at Hôpital Universitaire Necker–Enfants Malades with a diagnosis of traumatic SDH based on CT. The median age of these patients was 5.8 months (range 5 days–23 months), and 70% were male (male/female ratio 1.5:1). The GCS, modified for use in children under 2 years of

age, was applied to measure the level of consciousness; 69% of children were admitted with a GCS score of 12 or lower. Seizures were reported in 38% of cases and signs of ICH in 25%. Upon arrival, 18% had cutaneous signs of child abuse (bruises in various stages of absorption, abrasions, and burns). Ophthalmological examination revealed retinal hemorrhages in 65% of the children, and skeletal radiographs showed fractures in other regions of the body such as ribs and limbs in 16% of the cases (Table 1).

A bilateral SDH was demonstrated on CT scans in 52% of the children. In most cases (77%) the SDHs were homogeneously hypodense, while 16% were heterogeneous lesions in the subdural space (acute and subacute), and 13% were exclusively hyperdense (considered acute). Associated subarachnoid hemorrhages were identified in 11% of the cases and intraparenchymal hematomas in 5%. A skull fracture was identified in 7% of the cases, and brain edema and cerebral ischemia were noted on 1% of initial CT scans.

Emergency neurosurgical treatment was undertaken in 111 (60%) of the 184 children because of clinical evidence of ICH (bulging fontanel, increased vascular resistance on TCD ultrasonography) and an SDH diameter \geq 10 mm. Sixteen children (9%) who had a GCS score \leq 12 received only medical treatment (no surgery) either because no clinical signs of ICH could be detected and their SDHs were considered small or medium or because the patients' condition was unstable, with a GCS score of 3 and mydriatic pupils. The other 57 children had GCS scores $>$ 12 without clinical evidence of ICH and an SDH diameter $<$ 10 mm (small or medium) and did not receive surgical treatment.

The first surgical option was craniotomy in 1.8% of surgically treated patients (2 of 111), decompressive craniectomy in 1.8% (2), transcutaneous subdural puncture (maximum of 2 punctures) in 15% (17), external subdural drainage in 16% (18), subdural-subgaleal shunt placement in 17% (19), and subdural-peritoneal shunt placement in 48% (53). No reservoir implant was used. Considering all surgical procedures, 82% (14 of 17) of the patients initially treated with transcutaneous subdural puncture and 50% (9 of 18) of those initially treated with external subdural drainage needed additional surgical procedures. Infections were slightly more frequent in children treated with primary external subdural drainage (infection rate of 17%) and subdural-subgaleal shunts (10.5%) than in children with primary subdural-peritoneal shunts (4%). Initial surgical procedures and complications are presented in Table 2. Fourteen patients initially treated with subdural puncture and 9 initially treated with external subdural drainage subsequently underwent placement of either a subdural-peritoneal or subdural-subgaleal shunt. Of the 95 children treated with shunts, 89% (85 children) could be weaned from the shunts within the first 6 months after surgical procedure.

Six of the 184 children in our study cohort died. In all 6 cases, the children were admitted comatose or with epileptic seizures, with brain swelling beyond SDH in the CT scan. In 2 of the 6 cases, surgery was undertaken despite the severity of the patients' condition and hemodynamic instability; one of these patients was treated with emergency external subdural drainage and the other with

TABLE 1: Epidemiological profile of 184 children with a traumatic SDH and possible nonaccidental head injury*

Characteristic	Value
male sex	129 (70)
age	
median	5.8 mos
range	(5 days–23 mos)
GCS score \leq 12 at hospital admission	127 (69)
skin signs of abuse	33 (18)
presence of retinal hemorrhages	120 (65)
bone fractures	30 (16)

* Values represent numbers of children (%) unless otherwise indicated.

decompressive craniectomy. In the other 4 cases, the patients' condition was unstable, with a GCS score of 3 and mydriatic pupils, and the decision was made not to undertake surgical management.

It was not an aim of this study to evaluate neurological deficits or other disabilities.

Discussion

Traumatic SDH is a specific type of severe traumatic brain injury. When it occurs in neonates and toddlers, it is most often due to AHT. Musculoskeletal and cutaneous signs of child abuse can be absent in most cases, making the diagnosis of AHT more difficult, particularly as nonspecific signs of ICH can be confounding. A CT

TABLE 2: Surgical complications in 107* children stratified by initial procedure†

Complication	Initial Surgical Procedure			
	SP (n = 17)	ESD (n = 18)	SSS (n = 19)	SDPS (n = 53)
increase or persistence of SDH	14 (82)	5 (28)	2 (10.5)	6 (11)‡
CSF or skin infection	0	3 (17)	2 (10.5)	2 (4)
shunt malfunction§	0	1 (5)	1 (5)	5 (9)
other complications	1 (6)¶	—	—	1 (2)**
total	15 (88)	9 (50)	5 (26)††	14 (26)

* An additional 4 children underwent craniotomy (2 patients) or decompressive craniectomy (2 patients). Complications in these cases included infection (1 patient) and death (1 patient).

† Values represent numbers of children (%). ESD = external subdural drainage; SDPS = subdural-peritoneal shunt placement; SP = subdural puncture; SSS = subdural-subgaleal shunt placement.

‡ A contralateral SDH increase was observed in 6 (11%) of 53 cases, requiring contralateral SDPS in 5 (9.4%) of 53 cases.

§ Mechanical problem (shunt obstruction, displacement, or overdrainage).

¶ Puncture accident with subdural hemorrhage. No surgery proposed.

** Sigmoid colon perforation.

†† SDPS required in 4 cases.

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scan depicting SDH is the key for adequate diagnosis and should be considered early. In children less than 2 years of age with a traumatic SDH, an AHT must be strongly considered when accidental circumstances reported by parents or caregivers are not compatible with observed lesions.^{1,4,5,14,16,21} In the present study, all patients were considered possible victims of AHT because of their very young age (median 5.8 months) and the lack of history of accident or presence of disease that could explain the development of an SDH in a previously healthy child. Associated retinal hemorrhages were present in 65% of the cases in this series. This was a strong supplemental argument for AHT since retinal hemorrhages have been considered in previous reports as specific signs of abuse from a shaking mechanism when associated with SDH in neonates and toddlers without a clear history of trauma.^{1,8–10,12–14,16,19,22,24–26,29}

SDH is the most common finding on cranial CT scans of patients who are victims of AHT (present in > 70% of cases);^{2,3,7,8,23} it is commonly bilateral and sometimes associated with interhemispheric hyperdensity and/or convexity hemorrhages^{3,7,8,30} as we found in our sample. The SDHs in our patients were sometimes exclusively hyperdense (acute) or heterogeneous (acute and subacute), due to the natural sedimentation, accumulation of CSF and hemoglobin oxidation in different stages, or were homogeneously hypodense as described by some authors.^{3,29} Skull fractures and brain edema were observed in only a few of our patients. These findings are much more common in accidental head injury, as described in other studies.^{3,11,27–29} In patients with AHT, these findings may be associated with specific forms of abuse and violence, as in shaken baby syndrome or shaken impact syndrome.²³

Regarding the surgical approaches, we could not find a standardized protocol to treat patients less than 2 years of age with a traumatic SDH due to abuse. This difficulty has also been reported by other authors.^{17,31} The treatment of choice depends on the severity of the case (low GCS score and ICH), hematoma volume, and the experience and preference of the neurosurgeon. We routinely used an emergency surgical treatment in children with a GCS score ≤ 12 at hospital admission, signs of ICH (bulging fontanels, sunset eyes, Cushing triad, or increased vascular resistance on TCD ultrasonography), presenting with a large SDH (≥ 10 mm), as reported previously.^{17,20,29,31} Craniotomy and decompressive craniectomy were only indicated in exceptional cases in these children.¹⁷ In both children who underwent craniotomy, a massive acute SDH was observed with a midline shift and signs of ICH; and in the 2 children treated with decompressive craniectomy, in addition to a massive acute SDH, the patients were also found to have cerebral edema, refractory ICH, and hemispheric ischemia, which have been described by other authors as indications for this procedure.^{6,15} Probably our low rates of craniotomy for drainage of SDH and decompressive craniotomy or craniectomy are attributable to the low number of children with SDH in the acute phase.

Like others, we found that subdural puncture and external subdural drainage could be transiently effective but could not achieve complete resolution of SDH by themselves in most cases. These findings are correlated with cerebral hemodynamic modifications resulting from vari-

ous surgical procedures ascertained by TCD examinations demonstrating that cerebral hemodynamics could be only restored by definitive surgical treatment.²⁰ Surgical protocols could include subdural puncture (transcranial direct needle puncture) performed as an initial treatment on a daily basis or every 2 days; this treatment can be considered ineffective when a surgical SDH (≥ 10 mm) is still present on CT.^{17,29,31} Subdural puncture could be followed by external subdural drainage if the SDH is still large after approximately 1 week. For other patients, subdural puncture could be clearly ineffective, and external subdural drainage should be used as the first option in the presence of a large SDH. Moreover, external subdural drainage could be the most suitable initial intervention in critically ill, mechanically ventilated children and the procedure could be performed on an emergency basis at the bedside. Although transiently effective to decrease intracranial pressure and improve cerebral circulation, subdural puncture and external subdural drainage are rarely effective in the long term as definitive treatment for SDH. Our experience confirmed this point: 82% of the children benefiting from subdural puncture and 50% of those benefiting from external subdural drainage required further surgical intervention because a surgical SDH was still evident on CT after treatment.

Other proposed treatments include placement of a subdural-subgaleal shunt, sometimes with placement of subcutaneous reservoirs to allow periodic puncture and drainage of the hematoma,¹⁸ which can reduce the risk of occurrence of new subdural bleeding and infections, described in patients treated with direct puncture.^{17,18} In our neurosurgical department we had used subdural-subgaleal shunts (without reservoirs) since 2007 for most of our patients who were 3 months of age or younger in order to avoid external subdural drainage-related complications (mainly infection and accidental removal of the system), as we described before,¹⁷ and the additional surgical time and requirement for access to the abdominal cavity needed for placement of a subdural-peritoneal shunt.

The subdural-peritoneal shunt is widely used in the treatment of patients with traumatic SDH, particularly victims of AHT, and its use in these patients has been well described. It can be unilateral (preferably with implantation of the proximal catheter at the side of greater hematoma volume)¹⁷ or bilateral.³¹ The majority of patients have bilateral SDHs, which sometimes communicate. There is also the possibility of loculated SDH. Independent of whether unilateral or bilateral drainage is used, we prefer valveless systems.^{17,31} In our current series, there was a complication rate of about 26% for subdural-peritoneal shunts. This rate is similar to that reported in our previous surgical series involving patients treated before 2008.¹⁷ One of the complications from unilateral subdural-peritoneal shunt drainage is the increase of contralateral hematoma and the need to drain this contralateral SDH.^{17,31} This complication was present in 6 (11%) of 53 children treated with a subdural-peritoneal shunt in this case series, and all but one needed contralateral drainage. In our previous series,¹⁷ almost the same proportion of patients required a new contralateral shunt.

All shunt-treated children with traumatic SDH should be followed up after discharge (due to shunt implantation)

for 3 to 6 months, with follow-up CT scans. If hematoma regression is observed, the shunt can be removed, avoiding mechanical or infectious complications associated with the use of these devices.^{17,31} Removal of the shunt is recommended in these cases, but it is not free of risks. Complications, such as subdural hemorrhages due to adhesions of proximal catheter, may occur in up to 18.6% of cases.¹⁷ In our current series we observed that in 89% of the children it was possible to withdraw the shunt about 6 months after surgery without any severe complications during the first 6-month follow-up period after shunt removal.

Although there were only 6 deaths among the 184 children in this case series, this low mortality rate may be an underestimate due to selection bias. The most severely injured children may have died before they could be referred to our center and would thus not be represented in our patient group.

Conclusions

Performing craniotomy or decompressive craniectomy for the drainage of traumatic SDH may be considered in cases of massive acute SDH, associated with midline shift and refractory ICH. The choice to initiate treatment with subdural puncture, external subdural drainage, or placement of a subdural-subgaleal or subdural-peritoneal shunt should be made on a case-by-case basis, according to the clinical and radiological (CT) presentation. We recommend subdural puncture and external subdural drainage, both to be considered as temporary treatments, in emergency cases, mainly in hemodynamically unstable children with ICH, but noting that in some cases these procedures could be a definitive treatment. Placement of a subdural-subgaleal shunt is another valid surgical option, especially in light of the lower risk of infection (than external subdural drainage), shorter surgical time, and lack of a need for an abdominal approach (as required for a subdural-peritoneal shunt). Placement of a subdural-peritoneal shunt remains the most frequently used surgical technique in this group of patients, and either shunt system can be removed in most cases within 6 months after surgery if follow-up CT shows resolution of SDH.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Melo. Acquisition of data: Melo, Di Rocco. Analysis and interpretation of data: Melo, Di Rocco, Bourgeois. Drafting the article: Melo. Critically revising the article: Puget, Meyer, Zerah. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Melo. Administrative/technical/material support: Di Rocco, Blauwblomme. Study supervision: Meyer, Zerah.

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