JNS PEDIATRICS

CLINICAL ARTICLE

J Neurosurg Pediatr 23:480–485, 2019

Minicraniotomy with a subgaleal pocket for the treatment of subdural fluid collections in infants

Angela W. Palmer, MD,[1,2] and Gregory W. Albert, MD[1,2]

[1]Department of Neurosurgery, University of Arkansas for Medical Sciences; and [2]Division of Neurosurgery, Arkansas Children's Hospital, Little Rock, Arkansas

OBJECTIVE Various surgical techniques have been described to treat subdural fluid collections in infants, including transfontanelle aspiration, burr holes, subdural drain, subduroperitoneal shunt, and minicraniotomy. The purpose of this study was to describe a modification of the minicraniotomy technique that avoids the implantation of external drainage catheters and potentially carries a higher success rate.

METHODS In this retrospective study, the authors describe 11 cases involving pediatric patients who underwent parietal minicraniotomies for the evacuation of subdural fluid collections. In contrast to cases previously described in the literature, no patient received a drain; instead, a subgaleal pocket was created such that the fluid could flow from the subdural to the subgaleal space. Preoperative and postoperative data were reviewed, including neurological examination findings, radiological findings, complications, hospital length of stay, and findings on follow-up examinations and imaging. The primary outcome was failure of the treatment strategy, defined as an increase in subdural fluid collection requiring further intervention.

RESULTS Eleven patients (8 boys and 3 girls, median age 4.5 months) underwent the described procedure. Eight of the patients had complete resolution of the subdural collection on follow-up imaging, and 2 had improvement. One patient had a new subdural collection due to a second injury. Only 1 patient underwent aspiration and subsequent surgical repair of a pseudomeningocele after the initial surgery. Notably, no patients required subduroperitoneal shunt placement.

CONCLUSIONS The authors describe a new surgical option for subdural fluid collections in infants that allows for more aggressive evacuation of the subdural fluid and eliminates the need for a drain or shunt placement. Further work with more patients and direct comparison to other alternative therapies is necessary to fully evaluate the efficacy and safety of this new technique.

https://thejns.org/doi/abs/10.3171/2018.11.PEDS18322

KEYWORDS subdural hematoma; minicraniotomy; subgaleal pocket; nonaccidental trauma; surgical procedures; pediatric neurosurgery

Subdural collections, hematoma or hygroma, are a common problem faced by pediatric neurosurgeons. These subdural collections may enlarge over time and cause compression to the underlying brain parenchyma, resulting in focal or global neurological symptoms and accelerated head growth. Subdural collections in pediatric victims of trauma may evolve from acute subdural hematomas (SDHs) to chronic SDHs as is common in elderly patients. However, the subdural fluid collections in infants may also be subdural hygromas consisting of cerebrospinal fluid that arises from an arachnoid tear. Therefore, prolonged drainage may be necessary for resolution of the fluid collection.[18] The subdural collections may also be a combination of blood and CSF. Multiple treatment modalities have been employed in the past, including transfontanelle taps, subdural drains, subdural shunt placement, or burr hole/craniostomy for direct evacuation of the subdural fluid collection. There has been significant debate in the literature about the best treatment strategy.[1,10,13] All of these modalities, however, risk a reoperation for infection or recurrence of the subdural fluid.[12,16] Subdural shunts (subduroperitoneal and subdurosubgaleal), in particular, have long-term potential associated morbidity.[6] Klimo et al. have described a minicraniotomy for evacuation of the subdural fluid. Their technique included the use of a subdural drain that was left in place for 3–6 days.[8] The drain

ABBREVIATIONS SDH = subdural hematoma.

SUBMITTED May 27, 2018. **ACCEPTED** November 6, 2018.
INCLUDE WHEN CITING Published online February 1, 2019; DOI: 10.3171/2018.11.PEDS18322.

itself can be a conduit for infection, and it can prolong the child's hospital stay. Blauwblomme et al. have described the insertion of a subdurosubgaleal shunt through the anterior fontanelle.[1] In our case series, we reviewed a modification of the minicraniotomy technique wherein a large subgaleal pocket was used to allow the subdural space to communicate with the subgaleal space. We propose that this procedure for the treatment of chronic subdural collection results in the successful treatment of subdural collections without the need for implanted hardware. In addition, there seems to be a reduced incidence of reoperation.

Methods

Study Design

This study is a retrospective review of all cases of chronic subdural fluid collections treated by parietal minicraniotomy from 2011 through 2016 by a single surgeon and at a single institution. We included those children who were less than 1 year of age and who had chronic subdural fluid collections or mixed acute and chronic subdural collections. Patients were only included if they had undergone the novel minicraniotomy procedure with creation of a subgaleal pocket. We excluded those patients whose age exceed 1 year at time of surgery. No patients who met inclusion criteria were lost to follow-up. We were able to obtain at least 15 months of follow-up on all patients.

Preoperative clinical information that was collected included the patient's age in months at the time of presentation, sex, etiology of the subdural collection (if known), and presenting neurological status. We also gathered information about whether the patient was a premature newborn and whether the anterior fontanelle was full on initial presentation to the hospital. We noted whether there were concurrent long-bone or rib fractures, skull fractures, signs of trauma on the skin, retinal hemorrhages, or seizures. The CT studies of all patients were reviewed to determine if the subdural collection was chronic only or also had an acute component. All but one patient had MRI performed, so we also reviewed MR images as available. All patients with MRI except one had preoperative imaging. We recorded the indications for recommending surgical treatment as well as time from initial presentation to operative intervention. Intraoperative data included the color and appearance of the subdural fluid in most cases if it had been noted in the operative report. We also recorded data about any procedures preceding the minicraniotomy procedure. Postoperative information was collected including total number of hospital days and number of hospital days after surgery. Information about complications, including reoperations, recurrence of hematoma, reduction/resolution of the subdural fluid collections on postoperative follow-up scans, and infection, was also recorded. The local IRB determined that this study was exempt from IRB oversight.

Surgical Technique

Under general anesthesia, the patient was placed in a supine position with the head in a slightly flexed position. Inverted U-shaped incisions were made unilaterally or bilaterally such that the apex of the curve was just anterior to the coronal suture. The pericranium was preserved, and blunt dissection was used to dissect the subgaleal space widely, except for the forehead, which was left undisturbed for cosmetic purposes. The pericranium was then opened with monopolar cautery to create 3 sides of a rectangle based anteriorly on the coronal suture. A single burr hole was created in the midpoint of the posterior edge of the rectangle. Starting at this site, the craniotome was used to complete a parietal craniotomy based anteriorly on the coronal suture (Fig. 1 left). The bone flaps were then reflected anteriorly, maintaining the attachment to the coronal suture. The exposed dura was then coagulated and opened in a stellate fashion. The dural edges were coagulated, causing them to retract, which created a large opening (Fig. 1 right). Any subdural membranes were fenestrated if present. The subdural space was then copiously irrigated with saline until it ran clear. The bone flap was sutured back into place with a single absorbable suture, the galeal structure reapproximated, and the skin closed.

Results

Patient Characteristics

Of the 11 patients, 8 were male and 3 were female. The median age was 4.5 months. All but one of the patients were suspected to be victims of nonaccidental trauma. Four of the 11 patients were born prematurely. Over half of the patients had skeletal fractures, but only 27.3% had skull fractures in our series. Over half had seizure activity at time of presentation, and all but one of these with seizure activity had a full fontanelle on initial presentation. Five patients initially presented with flat fontanelles, but all of these patients demonstrated an increase in the fontanelle prior to operative intervention. Indications for surgery included an increase in fontanelle fullness, increase in subdural fluid collection size, and generalized signs of increased intracranial pressure. No patient was asymptomatic at the time of operative intervention. The mean time from initial emergency department presentation to operative intervention was 4.5 days. A complete summary of patient characteristics is provided in Table 1, and a complete list of indications for operative intervention is provided in Table 2.

Perioperative and Intraoperative Findings

Table 3 lists the intraoperative findings including appearance of the subdural fluid as well as procedures attempted prior to the minicraniotomy with subgaleal pocket. This was not the first surgical intervention for all patients, especially early in our series. One patient had undergone burr hole drainage alone, with subsequent increase in the subdural collection size and interval suture diastasis, and 3 patients had had fontanelle taps, with subsequent decline and an increase in subdural collection size. The other 7 patients had no prior intervention for the subdural fluid collection.

Outcomes

The primary outcome measure for this review was resolution of the patient's subdural fluid collection. Secondary outcomes included total and postsurgery hospital days and complications, including infection or death. The need

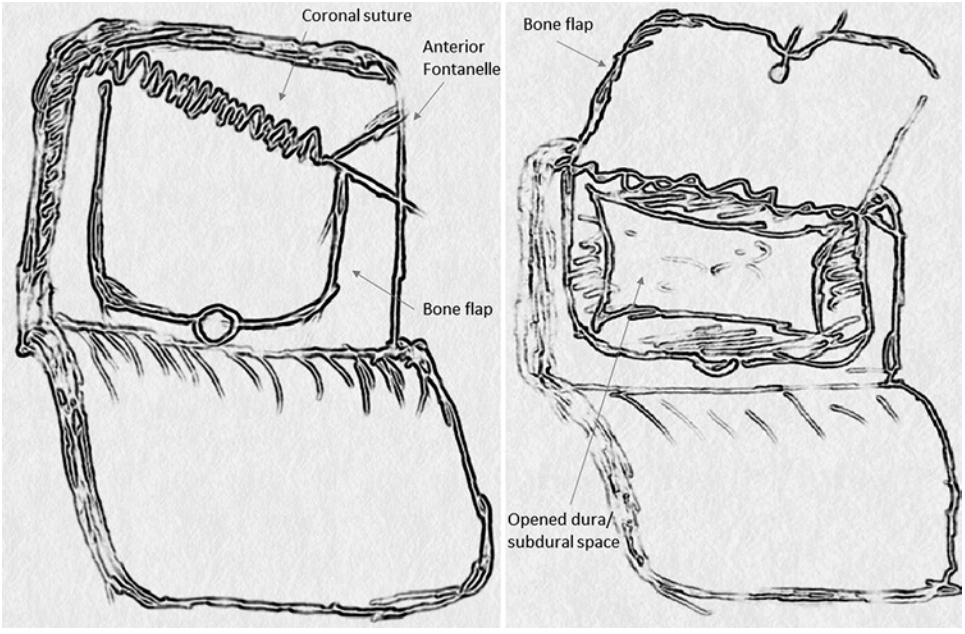

FIG. 1. Illustrations demonstrating the minicraniotomy technique. **Left:** The U-shaped incision is made just lateral to the anterior fontanelle such that the coronal suture is in the anterior-most portion of the skull exposure. A bone flap is created based on the coronal suture anteriorly, as shown. **Right**: The bone flap is elevated and reflected anteriorly. The dura is then opened widely to expose the subdural space.

for subsequent surgical intervention was also noted. Eight of 11 patients had complete resolution of the subdural collection on follow-up imaging (Fig. 2 left and right), and 2 of 11 had improvement (Fig. 3 left and right). The imaging was performed at nonstandardized intervals, and it may be the case that more time needs to pass prior to judging whether the procedure accomplished complete resolution. Imaging was performed from 1 to 12 months postoperatively in the group that had complete resolution of the subdural collection, and imaging was performed from 4 to 5 months postoperatively in the group that experienced only improvement of the size of the subdural collection. One patient did develop a new subdural collection, which was presumed to be related to a fall 3 months after the minicraniotomy procedure. No patients experienced infection or death. All patients had at least a 1-month follow-up visit, and all patients except 2 had at least 2 follow-up appointments with the neurosurgery clinic. Table 4 contains the outcomes data.

One patient underwent aspiration and subsequent surgical repair of a pseudomeningocele approximately 5 months after the initial surgery. Initially, the pseudomeningocele was aspirated, but it quickly recurred. Head CT revealed a persistent bone defect at the site of the minicraniotomy. The patient was taken to surgery, and this defect was occluded with a periosteal flap. After this repair, there was no recurrence of the pseudomeningocele or subdural fluid collection and no development of hydrocephalus. Of note, this was the only patient whose chronic subdural collection was attributed to coagulopathy rather than trauma.

Discussion

One of the most common findings on CT scanning of

TABLE 1. Characteristics of patients undergoing a minicraniotomy with a subgaleal pocket

Characteristic	Value
Sex	
Male	8/11 (72.7%)
Female	3/11 (27.3%)
Mean age (range), mos	4.5 (1–10)
Mean time from ED presentation to OR (range), days	4.5 (0–32)
Cause of subdural fluid collection	
Nonaccidental	10/11 (90.9%)
Protein S deficiency	1/11 (9.1%)
Premature newborn, %	36.3% (4/11)
Acute or SDH (CT & MRI if available)	
Acute & chronic	6/11 (54.5%)
Chronic	5/11 (45.5%)
Ventriculomegaly on CT scan	0/11 (0%)
Skeletal fractures	6/11 (54.5%)
Skull fractures	3/11 (27.3%)
Cutaneous signs of trauma	5/11 (45.5%)
Seizures	6/11 (54.5%)
Retinal hemorrhages	3/11 (27.3%)
Anterior fontanelle at ED presentation*	
Full	5/10 (50%)
Flat	5/10 (50%)

ED = emergency department; OR = operating room.
* One patient's chart did not reflect information about the anterior fontanelle, so this information was not able to be obtained for this patient.

TABLE 2. Indications for operative intervention

Indication for Operative Intervention	No. of Patients
Increase in fontanelle/head circumference	6
Apnea/bradycardia	2
Lethargy	3
Increase in subdural collection size	4
Seizures	1

the head in abusive head trauma in the pediatric setting is subdural fluid collections, either hematoma or hygroma, or a mix of the two. Collections of this nature are noted in over 70% of cases and are commonly bilateral.[2,7] Subdural collections often precipitate focal or global neurological symptoms from mass effect or elevated intracranial pressures. They can lead to enlarging head circumference, seizures, emesis, irritability, lethargy, or even developmental delay. The surgical management of these subdural collections is not standardized, although there are many treatment options. The ideal treatment has been debated in many previous articles, as each technique has advantages and disadvantages.[3,13,17] Ultimately there is a need for a safe and efficient means to treat these subdural fluid collections.

The subdural fluid collections seen in infants commonly have a consistency of CSF, perhaps with xanthochromia, rather than the "motor oil" appearance of chronic SDHs seen in the elderly. Zouros et al. demonstrated that these collections communicate with the lumbar subarachnoid space, suggesting that the subdural collections in infants are hygromas composed largely of CSF rather than pure hematomas.[18] Therefore, prolonged drainage of symptomatic fluid collections may be necessary to allow time for the arachnoid membrane to heal. Various options have been proposed to address this need, including external drainage (fontanelle tap, subdural drain) and internal drainage (subdurosubgaleal shunt, subduroperitoneal shunt).

External drains are effective 60%–95% of the time for at least a short period, but they prolong the hospitalization period, increasing cost of care as they must remain in place for an average of 3–9 days.[1,11] Almost half of all patients treated with external subdural drainage will eventually need additional procedures according to some studies, and

TABLE 3. Perioperative and intraoperative data

Periop & Intraop Data	No. of Patients
Appearance of subdural fluid	
Motor oil	1
Xanthochromic & consistency of CSF	5
Not listed	5
Preceding procedure	
Fontanelle tap	3
Burr hole drainage	1
None	7

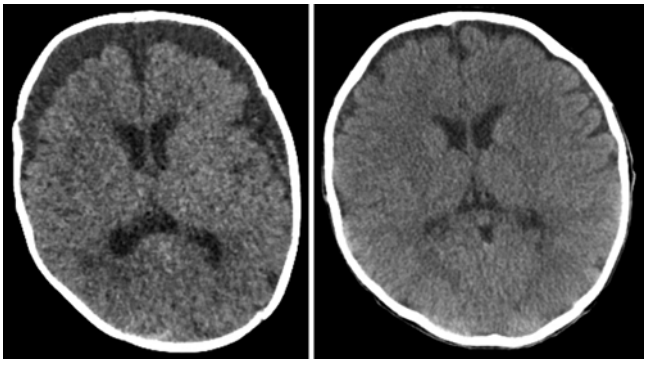

FIG. 2. Left: Representative CT scan before surgery of a patient with full resolution of the subdural fluid collection. **Right:** Representative CT scan 5 months postoperatively of a patient with full resolution of the subdural fluid collection.

17% of these are secondary to infection.[4,6,13,17] Shunting of the subdural fluid is another option for treatment. Subduroperitoneal shunting can be successful in the treatment of chronic subdural collections in infants over 90% of the time, likely because pediatric neurosurgeons have ample experience with shunt surgery.[9,17] However, these shunt systems are subject to long-term morbidity and complications 15%–25% of the time, among other less common complications such as bowel perforation.[5,13,17] Another treatment option is subdurosubgaleal shunting, which carries an even higher potential risk of infection (over 10%) or malfunction.[13] Infants are able to absorb fluid from the subgaleal space as demonstrated with ventriculosubgaleal shunts, and it has been demonstrated that this fluid-absorbing surface can work well for up to 20 months.[14,15]

Craniotomy has also been described for treatment of chronic subdural collections in infants and has the advantage of access to inflammatory membranes that are often associated with these fluid collections. With a craniotomy, there is improved ability to visualize the subdural space, and this allows for more aggressive evacuation of subdural fluid. This is an effective treatment option, but it traditionally required a large access craniotomy. More recently in a paper by Klimo et al., a bilateral parietal "minicraniotomy" technique was described that reduced the size of the bone opening in hopes that the procedure could be

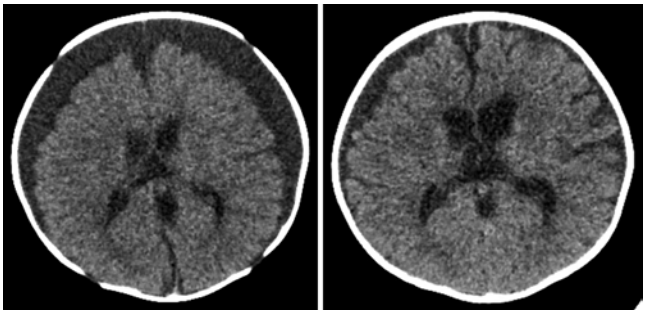

FIG. 3. Left: Representative CT scan before surgery of a patient with incomplete resolution of the subdural fluid collection. **Right:** Representative CT scan 2 months postoperatively of a patient with incomplete resolution of the subdural fluid collection.

TABLE 4. Outcome measures of the 11 patients treated with minicraniotomy and a subgaleal pocket procedure

Outcome Measure	Value (range)
Hospital length of stay, days	
Overall average	15 (3–32)
Postop average	11 (1–24)
Additional procedures	
None	10/11
Repair of pseudomeningocele	1/11
Postop subdural collection (CT scan)	
Resolved	8/11
Improvement	2/11
Interval increase*	1/11
Infection or other complication	0/11

* Patient fell 3 months postoperatively and developed a new subdural collection.

better tolerated.[8] Fifteen patients underwent this procedure, which included a drain placement in all cases, and these patients' outcomes were compared to those of age-matched controls who underwent burr hole evacuation followed by external drainage. Treatment failure was defined as requiring subsequent surgery. Only 13% of patients in the minicraniotomy group in this series required subsequent procedures compared to 45% of those in the burr hole group. The described minicraniotomy procedure had excellent preliminary success, but some of these patients still experienced treatment failure. In addition, these patients required externalized drains, which may have prolonged their inpatient stays and are a potential source of infection.

Given the success of the minicraniotomy procedure, we modified this technique utilizing the principle that infants can absorb fluid from the subgaleal space if only required for a temporary time frame. We believe that the minicraniotomy technique coupled with the subgaleal pocket creates a means to shunt fluid from the subdural space to the subgaleal space without the use of an indwelling catheter. Ideally, the opening will remain patent until the subdural fluid collection resolves, and then it will scar down, obliterating the subgaleal space. This procedure eliminates the traditional concern of increased infection risk and malfunction associated with indwelling catheter shunt systems. There is no need for an external drain with this approach, thus reducing the risk for infection.

The majority of these patients had fluid collections diffusely throughout the subdural space on both sides of the head. While the subdural space does communicate across the midline, and therefore it is conceivable that unilateral drainage would be all that is needed, we elected to treat our patients with bilateral surgery. We felt that this gave the best chance for successful intervention to ensure maximum drainage of the subdural space. In addition, the second minicraniotomy was not thought to substantially increase the risk of the surgery. Finally, the minicraniotomy procedure described by Klimo et al., which was the starting point for this approach, also used bilateral minicraniotomies.[8]

We were able to clear the infant for discharge on postoperative day 1, which creates an opportunity for cost savings through shorter hospitalizations. The average hospital stay, however, was 11 days postsurgery, but this lengthy hospital stay was related primarily to the social and legal aspects of the management of nonaccidental trauma. In cases that do not involve a traumatic cause of SDH, the number of hospital days could be reduced dramatically.

In our series, there was one patient whose subgaleal pocket did not spontaneously resolve. This patient was the only one in the series whose initial subdural fluid collection was attributed to coagulopathy rather than trauma. None of the patients whose chronic subdural collection was related to nonaccidental trauma required additional surgery to treat the subdural collection. However, one patient did return to clinic after a fall approximately 3 months after the index procedure and experienced a recurrence of the right-sided SDH. She was taken back to the operating room, and a repeat minicraniotomy with subgaleal pocket was successful at evacuating the recurrent SDH.

The minicraniotomy with subgaleal pocket technique does have some disadvantages. The procedure does require for the patient a visit to the operating room under general anesthesia, unlike external subgaleal drain placement or fontanelle taps, which can be performed as a bedside procedure. Another disadvantage is that this procedure does create a temporary increase in head size because of accumulation of subgaleal fluid, which was cosmetically displeasing to some of the families.

Study Limitations

The preliminary results from a retrospective chart review of all infants treated with the minicraniotomy plus a subgaleal pocket procedure are promising. This case series serves as a description of a new technique and includes only 11 patients. More patients and a control group would be needed to be able to better evaluate this treatment strategy and discover the effects of potential confounding variables. Additionally, this is a retrospective chart review. Postoperative imaging follow-up was not performed at standardized intervals, so it was difficult to precisely assess time to complete resolution of the subdural collection. Hence, some patients had only improvement of the subdural fluid rather than complete resolution; this finding may have been different if follow-up imaging had been performed at a later interval. Direct neurosurgery follow-up notes were not available for all of the patients past the 1-month postoperative visit, so some of the patient follow-up data at 3–12 months relies upon other services, such as emergency room visits and pediatric clinic follow-up.

Conclusions

There is no consensus on the optimum treatment strategy for those children with subdural fluid collections. We have described a new management option that allows for the advantages of the minicraniotomy, including the ability to more aggressively evacuate the subdural fluid, and that obviates the need for a drain by utilizing the infant's ability to absorb fluid readily from the subgaleal space.

This treatment strategy represents a way to definitively treat infant subdural fluid collections and avoid a catheter-based procedure. Based on our experience, we suggest this may be a good surgical strategy given the preliminary finding of a low complication rate and high success rate. However, further work with more patients and direct comparison to other alternative therapies is necessary to fully evaluate the efficacy and safety of this new technique.

References

1. Blauwblomme T, Di Rocco F, Bourgeois M, Beccaria K, Paternoster G, Verchere-Montmayeur J, et al: Subdural to subgaleal shunts: alternative treatment in infants with non-accidental traumatic brain injury? **J Neurosurg Pediatr 15:**306–309, 2015
2. Bradford R, Choudhary AK, Dias MS: Serial neuroimaging in infants with abusive head trauma: timing abusive injuries. **J Neurosurg Pediatr 12:**110–119, 2013
3. Caldarelli M, Di Rocco C, Romani R: Surgical treatment of chronic subdural hygromas in infants and children. **Acta Neurochir (Wien) 144:**581–588, 2002
4. Erşahin Y, Mutluer S, Kocaman S: Continuous external subdural drainage in the management of infantile subdural collections: a prospective study. **Childs Nerv Syst 13:**526–529, 1997
5. Ersahin Y, Tabur E, Kocaman S, Mutluer S: Complications of subduroperitoneal shunting. **Childs Nerv Syst 16:**433–436, 2000
6. Gaskill SJ, Oakes WJ, Marlin AE: Continuous external drainage in the treatment of subdural hematomas of infancy. **Pediatr Neurosurg 17:**121–123, 1991–1992
7. Kesler H, Dias MS, Shaffer M, Rottmund C, Cappos K, Thomas NJ: Demographics of abusive head trauma in the Commonwealth of Pennsylvania. **J Neurosurg Pediatr 1:**351–356, 2008
8. Klimo P Jr, Matthews A, Lew SM, Zwienenberg-Lee M, Kaufman BA: Minicraniotomy versus bur holes for evacuation of chronic subdural collections in infants—a preliminary single-institution experience. **J Neurosurg Pediatr 8:**423–429, 2011
9. Korinth MC, Lippitz B, Mayfrank L, Gilsbach JM: Subdural-atrial and subdural-peritoneal shunting in infants with chronic subdural fluid collections. **J Pediatr Surg 35:**1339–1343, 2000
10. Kurschel S, Puget S, Bourgeois M, Zerah M, Ofner P, Renier D: Factors influencing the complication rate of subduroperitoneal shunt placement for the treatment of subdural hematomas in infants. **J Neurosurg 106 (3 Suppl):**172–178, 2007
11. Lin CL, Hwang SL, Su YF, Tsai LC, Kwan AL, Howng SL, et al: External subdural drainage in the treatment of infantile chronic subdural hematoma. **J Trauma 57:**104–107, 2004
12. Litofsky NS, Raffel C, McComb JG: Management of symptomatic chronic extra-axial fluid collections in pediatric patients. **Neurosurgery 31:**445–450, 1992
13. Melo JR, Di Rocco F, Bourgeois M, Puget S, Blauwblomme T, Sainte-Rose C, et al: Surgical options for treatment of traumatic subdural hematomas in children younger than 2 years of age. **J Neurosurg Pediatr 13:**456–461, 2014
14. Perret GE, Graf CJ: Subgaleal shunt for temporary ventricle decompression and subdural drainage. **J Neurosurg 47:**590–595, 1977
15. Savitz MH, Malis LI: Subgaleal shunting: a 20-year experience. **Neurosurg Focus 9(6):**ecp1, 2000
16. Tolias C, Sgouros S, Walsh AR, Hockley AD: Outcome of surgical treatment for subdural fluid collections in infants. **Pediatr Neurosurg 33:**194–197, 2000
17. Vinchon M, Noulé N, Soto-Ares G, Dhellemmes P: Subduroperitoneal drainage for subdural hematomas in infants: results in 244 cases. **J Neurosurg 95:**249–255, 2001
18. Zouros A, Bhargava R, Hoskinson M, Aronyk KE: Further characterization of traumatic subdural collections of infancy. Report of five cases. **J Neurosurg 100 (5 Suppl Pediatrics):**512–518, 2004

Disclosures

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

Conception and design: Albert. Acquisition of data: Palmer. Analysis and interpretation of data: both authors. Drafting the article: Palmer. Critically revising the article: both authors. Reviewed submitted version of manuscript: both authors. Approved the final version of the manuscript on behalf of both authors: Albert. Study supervision: Albert.

Supplemental Information

Previous Presentations

Portions of this work were presented in abstract and oral presentation forms at the Southern Neurosurgical Society Annual Meeting, Marco Island, FL, March 3, 2018.

Correspondence

Gregory W. Albert: Arkansas Children's Hospital, Little Rock, AR. galbert2@uams.edu.