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Subduroperitoneal drainage for subdural hematomas in infants: results in 244 cases

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Object. Subduroperitoneal drainage (SDPD) is commonly used in the treatment of infantile subdural hematomas (SDHs). Few studies have focused on this technique and most series have included SDHs of various origins in children of different ages. The surgical procedure is not standardized and results achieved using this technique have not been well documented.

The authors reviewed their cases of traumatic SDH treated with SDPD in infants (< 2 years of age). Their standard technique includes bilateral SDPD whenever the SDH is bilateral, placement of a free shunt, and systematic removal of the drainage unit after a few months.

Methods. The authors performed SDPD in 244 infants with traumatic SDH. The patients' SDHs were controlled by SDPD in 241 cases, and 78.9% of the patients recovered to live a normal life. Complications of SDPD occurred in 38 patients (15.6%): obstruction in 22 cases (9%), infection in eight cases (3.28%), and internal hydrocephalus in eight cases (3.28%). Early complications could be ascribed to surgical technique, delayed complications were associated with the severity of the initial clinical presentation, and late complications were time dependent and unrelated to initial clinical severity. Poor clinical outcome was correlated to the severity of the initial presentation, but not to complications of surgery.

Conclusions. Because of its efficacy and low complication rate, SDPD is the procedure of choice when subdural taps fail to control SDH. The authors prefer bilateral drainage because of the low rate of complications. Drains should be systematically removed after a few months to prevent long-term complications.

KEY WORDS • subdural hematoma • trauma • head injury • subduroperitoneal drainage • infant

INFANTILE SDHs are common complications of head injuries. They occur most frequently in children younger than the age of 2 years and pose specific therapeutic problems. Therapeutic strategies for such lesions are much debated; in particular, there is no consensus regarding indications for surgery or the most appropriate surgical technique.[1,8,12,18,21,26] In addition, most pediatric series are composed of both infants and older children and do not differentiate between posttraumatic SDH and SDH arising from meningitis, tumor removal, or ventricular hyperdrainage.[5,6,16,26] Since its introduction more than 40 years ago, SDPD has become one of the most commonly performed treatments of infantile SDH,[6,16] but the most appropriate surgical technique and timing of surgery are still much debated. Moreover, the success and complication rates of this technique have not been well documented in the literature. Consequently, the value and indications of SDPD for traumatic SDH in infants have not yet been established. For more than 20 years at our institution we have managed infantile traumatic SDH in a standardized fashion by using SDPD as the routine technique and by systematically removing the drainage unit after a few months. We reviewed our experience with SDPD and systematic removal of the drainage unit in infants with traumatic SDH, with special emphasis on clinical results and complication rates.

Abbreviations used in this paper: CI = confidence interval; CSF = cerebrospinal fluid; CT = computerized tomography; MR = magnetic resonance; SDH = subdural hematoma; SDPD = subduroperitoneal drainage; VP = ventriculoperitoneal.

Clinical Material and Methods

Patient Population

We reviewed the cases from 1978 to 2000 of infants younger than 2 years of age at the time of surgery who underwent SDPD for SDH. During that period, cases were managed in a standardized fashion and followed prospectively. Patients were excluded if SDH occurred after tumor removal or ventricular drainage or was associated with arachnoid cysts, meningitis, or metabolic disorders. Cases of external hydrocephalus or benign enlargement of the subarachnoid spaces were excluded as well, based on neuroimaging and, in some cases, on the macroscopic ap-

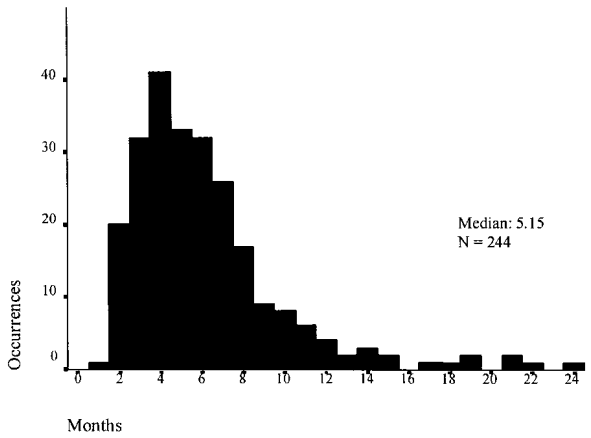

FIG. 1. Bar graph showing the age distribution of patients at the time of surgery. Subdural hematomas are almost specific to infants younger than 1 year of age. The sharp decline in incidence as patients age coincides with the acquisition of sitting and standing postures, suggesting an earlier period of increased vulnerability.

pearance of the subdural fluid. Patients were included in the series if SDH was associated with identified trauma or could not be ascribed to any other cause of SDH. Many patients included in the series harbored an SDH without an identified cause because, at the beginning of the study, the degree of suspicion toward child abuse was low and many SDHs were considered spontaneous. In retrospect, many of these cases were probably due to shaken-baby syndrome. Because of the surgical bias, our series does not allow calculation of the proportion of head-injured children requiring SDPD.

Case Management

The infants were admitted to our department either after the initial trauma or at the time SDH was diagnosed. More severely affected children were initially admitted to the intensive care unit and transferred to our ward at the time of surgery. Computerized tomography scanning was performed in every case. Because it required general anesthesia, MR imaging was performed only in selected cases (mainly inflicted trauma) to assess brain damage and study the cervical spine or when additional treatment was being discussed after failure of SDPD. The initial treatment of SDH systematically consisted of subdural punctures that were repeated as needed, usually every day or every 2nd day. The decision to operate was made after failure of at least two subdural punctures.

Surgical Technique

At the beginning of our experience, a few patients underwent placement of an SDPD unit with a low-pressure valve. Except for these few exceptions, the standard technique used in our department is SDPD with no valve. In most cases, the SDH is bilateral and our preferred technique is bilateral SDPD. In the absence of evidence in favor of unilateral or bilateral drainage, we chose that surgical option from the beginning of the series and adhered to it all throughout the period of the study.

Postoperative Care

After the initial postoperative period, each infant was either discharged or transferred to a pediatric department or nursery if needed. In cases of suspected child abuse, the hospital stay was often longer than needed on medical grounds because our legal system has ruled that the decision to discharge such a child from the hospital must be made by a judge. Each child was observed postoperatively by means of clinical evaluations and CT scanning performed 3 to 6 months after SDPD was initiated. Once regression of the SDH was confirmed, the SDPD unit was removed while the patient was in a state of general anesthesia. The child was discharged 2 days later, observed in outpatient clinics for 6 months, and, finally, subjected to clinical and psychological evaluation at the age of 6 years.

Statistical Analysis

Statistical analysis was performed using commercially available computer software (SPSS version 9.0.1; SPSS Inc., Chicago, IL), with a probability value of 0.05 for statistical significance. Confidence intervals were calculated to compare percentages. Correlations were tested using the chi-square test for binary variables, the Student t-test for comparison of means, and the Wilcoxon z-test for ordinal variables. Survival analysis was performed using the Kaplan–Meier method with the log-rank test for statistical significance. The correlation between multiple variables and the occurrence of shunt complications were studied using logistic regression analysis, and the correlation between variables and outcome were tested using linear regression analysis.

Results

Diagnosis and Treatment

Between November 1978 and June 2000, we treated 244 infants with traumatic SDH by using SDPD. The infants were aged 0.5 to 23.5 months (mean 6.13 $\pm$ 3.78 months, median 5.15 months) at the time of surgery, and 166 of them (68%, span of 95% CI 5.85%) were male. The patients' age distribution is shown in Fig. 1. Head injuries were nonaccidental (Silverman syndrome or shaken-baby syndrome) in 71 cases (29%), caused by domestic accidents in 36 cases (14.8%), caused by traffic accidents in 21 cases (8.6%), and reportedly not due to trauma in 116 cases (47.5%). The median time between trauma and admission to the hospital was 9.5 days (range 0–8.2 months).

Presenting symptoms included intracranial hypertension (118 cases [48.4%]), epilepsy (112 cases [45.9%]), enlarged head (63 cases [25.8%]), hypotonia (20 cases [8.2%]), localized deficit (nine cases [3.7%]), and delayed milestones (six cases [2.5%]). Clinical presentation was severe (that is, associated with coma, status epilepticus, or deficit) in 44 cases (18%) and mild in the remaining 200 cases (82%). All patients underwent CT scanning preoperatively. In a few cases, MR imaging was also performed to assess the nature of the fluid and to determine the date of trauma from a forensic perspective (Figs. 2 and 3).

The median time between admission to the hospital and surgery was 4 days (range 0–57 days) and the median time between trauma and surgery was 17 days (range 2 days–

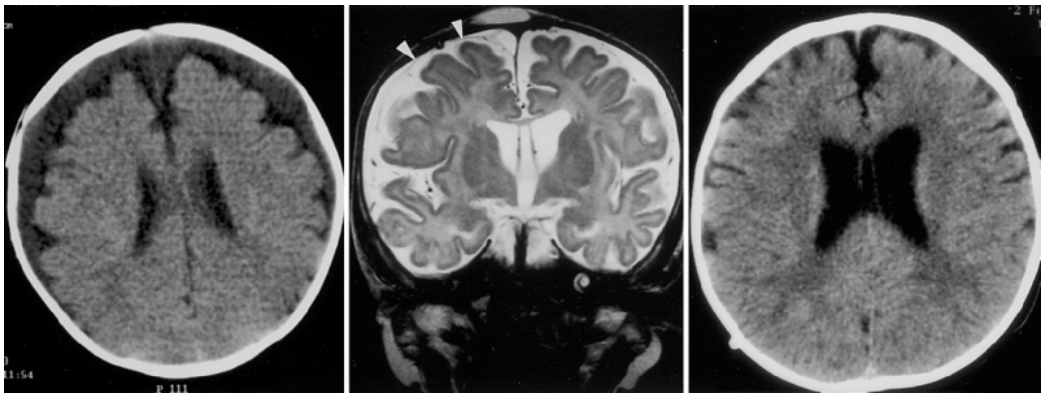

FIG. 2. Neuroimaging obtained in a 2-month-old male infant with a large head at birth (head circumference 40 cm), who presented with signs of raised intracranial pressure without any history of trauma. *Left:* Initial axial CT scan revealing the association of SDH and expanded sulci. Intracranial hypertension was not relieved by subdural taps and the patient underwent insertion of a SDPD unit 6 days after admission, resulting in complete resolution of symptoms. *Center:* Postoperative frontal T_2-weighted MR image obtained 2 months later, demonstrating partial collapse of the SDH and healing of the outer layer of the arachnoid around the catheters *(arrowheads)*. *Right:* Axial CT scan obtained 6 months after drainage, but before shunt removal, confirming complete resolution of the subdural collection.

8.8 months). The SDPD unit consisted of a valve-regulated shunt in 13 cases (performed in 1979 and 1980); a free shunt was used in the remaining 231 cases. Drainage was bilateral in 94.6% of the cases and unilateral in 5.4%.

The mean duration of hospital stay was 15.3 ± 8.1 days (range 0–64 days). The mean postoperative stay was 9.7 ± 4.7 days (range 2–39 days). The mean postoperative hospital stay in cases in which there was suspicion of inflicted trauma was 11 ± 6.2 days (span of 95% CI 1.4 days), compared with 9.4 ± 3.8 (span of 95% CI 0.84 days) in the accidental trauma group (nonsignificant difference).

Follow-Up Review and Complications

The mean duration of follow up after surgery was 34.6 ± 38.8 months (range 0–231 months). During that period, complications related to SDPD occurred in 38 patients (15.6%). Shunts were removed without complications in 203 patients; three other patients were lost to follow up while their shunts were still in place.

Eight patients presented with infectious complications (3.28%) 5 days to 7 months after surgery. Four of these complications occurred more than 1 month after surgery. One patient with a scarred peritoneum experienced bowel perforation at the time of surgery and presented with peritonitis requiring emergency laparotomy and removal of the SDPD unit 5 days after its insertion. Another patient presented with anal extrusion of the peritoneal catheter 7.3 months after SDPD placement. Six other infectious complications involved the central nervous system, with three of these being associated with a subdural empyema 12 to 79 days after surgery. In one patient, the infectious complication occurred after the patient experienced chicken pox complicated by staphylococcal impetigo. No case of infection has been recorded since 1994 in 66 consecutive cases.

Obstruction of the SDPD unit requiring repeated surgery occurred in 22 cases (9%). Detailed information about the level of obstruction is available in 16 cases: in 10 of these, the subdural catheters were clogged, requiring membrane resection in two cases and revision of the SDPD unit in the eight others. In five cases the peritoneal catheter was obstructed and in one it was disconnected. In five of these 22 patients, a second episode of shunt obstruction occurred, requiring two more membrane resections and three shunt revisions. All three patients undergoing membrane resection initially presented with a severe clinical status.

Hydrocephalus requiring placement of a VP shunt complicated the course of the disease in eight cases (3.28%). In five of these cases, hydrocephalus appeared before removal of the SDPD unit and in the three others it appeared 31 to 45 days after removal. In one case, the VP shunt be-

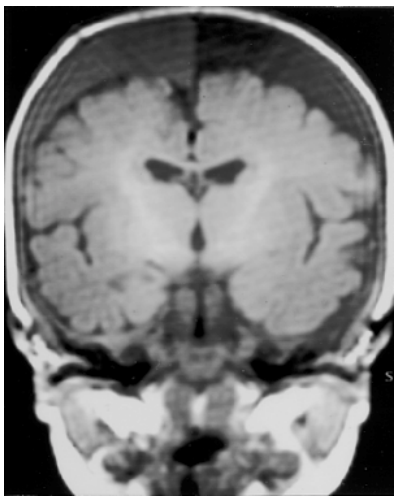

FIG. 3. Postoperative frontal T_1-weighted MR image obtained 12 days after shunt insertion in a 2-month-old male infant with shaken-baby syndrome who presented with seizures and raised intracranial pressure. The subdural collection is clearly delineated from the subarachnoid space, and the protein content is distinctly different on both sides. One day after the MR image was obtained, the infant underwent a second surgery because the peritoneal end of the shunt was obstructed. His postoperative course was uneventful.

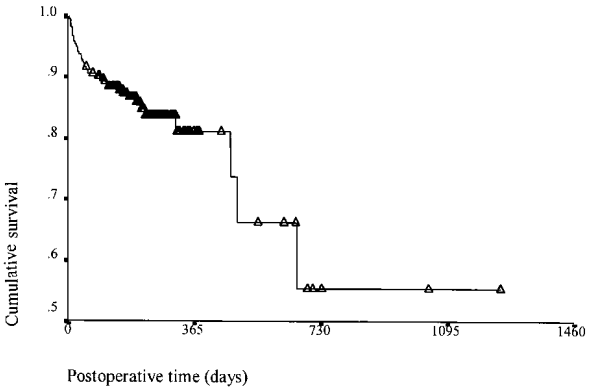

FIG. 4. Kaplan–Meier survival curve showing the overall incidence of SDPD complications related to postoperative time. *Triangles* indicate patients in whom the shunt was removed systematically or who were without complication at the last control examination. Most SDPD units were removed within 6 months after insertion. For the remaining shunts, complication-free survival stabilized after 3 years at 55.3%, and the estimated annual incidence of complications was 17.9% during the first 3 postoperative years.

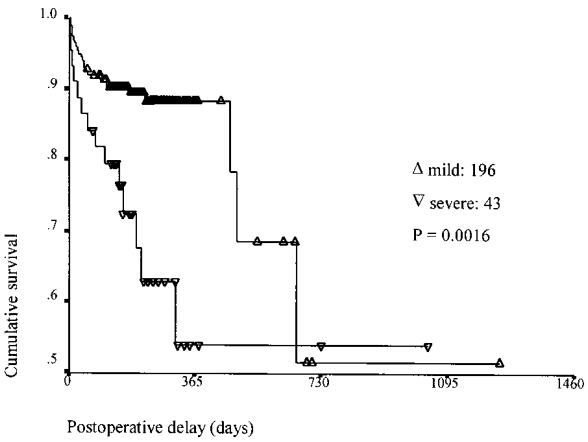

FIG. 5. Kaplan–Meier complication-free survival curves for patients with SDPD, stratified according to their initial clinical status (severe = deficit, coma, or status epilepticus). The complication-free survival time was significantly lower for patients with severe clinical status at the time of surgery, although the final complication rate was similar in both groups. This suggests that complications can be separated into two groups: early complications, which are associated with clinical severity, and late time-dependent complications.

came nonfunctional and was removed 13.7 years after its insertion. The incidence of definitive shunt dependence in this series was 2.87%.

The overall incidence of complication was significantly associated with a severe initial clinical state ($p = 0.013$), long preoperative hospital stay ($p = 0.016$), and long time between trauma and surgery ($p = 0.037$). The incidence of complications of SDPD as a function of time is depicted in Fig. 4: it shows that after a sharp decrease in the postoperative period, survival rates continue to decrease steadily thereafter and throughout the following 3 years. Although shunts are now systematically removed 5 months postoperatively, at the beginning of our experience many shunts were left in place for longer periods. We were therefore able to estimate the long-term incidence of complications. The complication-free survival rate stabilized at 55.3% after 3 years. The estimated incidence of complications was 17.9% per year during the first 3 years after shunt placement. The complication-free survival of patients with mild clinical status was significantly better than that of patients with severe symptoms, although the final complication rate was similar for both groups (Fig. 5).

Patient Outcomes

None of our patients died after surgery; in one case, head injury was not initially ascribed to ill treatment and the child died of repeated child abuse. The other children are all alive. When last reviewed, the mean age of the patients was 40.9 ± 38.7 months (range 3–244 months). Among the 242 children in whom there was adequate follow up, the Glasgow Outcome Scale scores were 5 (normal health) in 192 cases (79.3%); 4 (mild disability, but could lead a normal life) in 30 (12.4%); 3 (severe disability) in 12 patients (5%); and 2 (vegetative state) in eight cases (3.3%). The most common handicap was cognitive deficit in 39 cases (16%), followed by motor deficit in 24 cases (9.8%), visual loss in 23 cases (9.4%), behavioral problems in 19 cases (7.8%), and epilepsy in 17 cases (7%). Poor outcome was associated with the severity of the initial clinical presentation ($p < 0.001$), but was not affected by the occurrence of shunt complications ($p = 0.27$).

Discussion

Pathophysiological Considerations

Traumatic SDH in children younger than the age of 2 years accounts for most cases of infantile SDH in every series and raises specific diagnostic and therapeutic problems; however, meningitis- and VP shunt–related SDH and SDH secondary to tumor removal concern a marginal set of patients with specific pathogenesis and complication risks. We therefore considered it appropriate to focus on traumatic SDH in infants. Subdural hematoma is an accumulation of bloody fluid in an abnormal space resulting from a cleavage of the outer layer of the arachnoid.[7,11] Infantile traumatic SDH is a specific pathological entity and may be due to the immaturity of arachnoid villi before the child achieves walking age,[4,25] as suggested by the age distribution (Fig. 1). In some cases, the child presents with macrocrania and increased pericerebral CSF before the onset of SDH,[13,21] and trauma may be so mild it can go unnoticed. After the initial trauma, an SDH can grow without any further trauma due to tearing of bridging veins[11] or rebleeding associated with neoangiogenesis in the outer membrane.[7] Initially, the fluid is very thin, and becomes even thinner after subdural tap or external drainage,[13,26] providing evidence that the blood is progressively replaced with CSF. Impaired CSF absorption at the level of the arachnoid granulations may result from an extended cleavage in the outer arachnoid membrane into the arachnoid villi and a collapsing subarachnoid space[25] or from the proliferation of arachnoid cap cells, as evidenced in cases of subarachnoid hemorrhage.[17] Proceeding from this

pathogenic hypothesis, the rationale of subdural drainage is to bring the separated layers of the outer arachnoid membrane into contact, allowing the meninges to heal and reestablishing adequate CSF absorption (Fig. 2). Four to 6 months after surgery, children are able to sit or stand. The arachnoid villi are functional and brain has grown and caught up with the skull. The SDH is permanently cured, and the shunt becomes useless.

Therapeutic Indications and Timing of Surgery

The object of the treatment is to relieve intracranial hypertension and prevent the complications of SDH, namely brain atrophy, visual loss, and craniocerebral disproportion. Medical treatment of SDH is nonexistent; the use of acetazolamide can be effective for external hydrocephalus, but it does not affect the course of SDH. Fluid subtraction by subdural tap through the larger fontanelle or the calvarial bone is widely accepted as the first treatment of SDH and is often performed in emergency situations.[2,17,19,23] Although it provides immediate relief, the collection of fluid often recurs within a few days, requiring additional subdural taps. Repeated subdural taps have been suspected of inducing the reconstitution of SDH[21] and, on occasion, of initiating the late appearance of intracranial dermoid cysts.[10] For these reasons, other treatments are often required.[16,18]

Burr-hole evacuation is only infrequently efficient, and many patients require additional operations.[16] Endoscopic washout is an elegant improvement on the method and has yielded interesting results in a limited experience; it may become a technical standard in the future if its results are confirmed.[9]

In the past, creation of a large craniotomy to remove subdural membranes was deemed necessary to prevent SDH recurrence and to release the brain from the compressive effect of the membranes.[18] This operation now has very few indications, mainly persistent uncontrolled SDH after one or more shunting procedures. In our series, we only had to resort to the procedure in three patients who initially underwent surgery while in a severe clinical state. We attributed the failure of SDPD to the unusual thickness of these patients' membranes and to associated brain atrophy.

The advantages of external subdural drainage are supported by several authors,[5,8,26] especially as a means to avoid permanent placement of a drainage unit. Nevertheless, this technique bears a risk of septic complications,[23] requires a prolonged hospital stay in many cases,[26] may cause electrolyte imbalance,[5] and complicates nursing. Moreover, secondary internal drainage cannot be avoided in as many as 50% of cases,[5,8] and an SDPD unit inserted after failure of external drainage is more likely to be permanent, resulting in a higher final percentage of patients with shunts than in our series.[26] Although external drainage is the standard technique for SDH in adults at our institution, we limit its use in children to postmeningitic subdural collections.

Internal drainage was suggested as early as 1965[23] and is generally the definitive solution for SDH,[20] although obstruction may occur and require shunt revision.[16] Opponents of SDPD point to the surgical risks and financial costs associated with the technique.[5,8,19] To this day, our series is the largest reporting results of this technique and focusing on infantile traumatic SDH. We found an obstruction rate of 9%, an infection rate of 3.3%, and a permanent shunt-dependency rate of 2.9%. These complication rates seem acceptable in light of the initial seriousness of the condition and the potential threat of SDH. In our opinion, SDPD is also the best way to bypass the vicious circle of SDH. It is a safe one-stage procedure that allows quick recovery and hospital discharge, reduces the stress experienced by patient and parents, and limits the need for repeated CT scanning (which often requires induction of anesthesia in this age group). Other techniques have marginal indications in our practice.

The optimal time before implementing SDPD has been debated: some authors prefer to repeat subdural taps for as many as 2 weeks,[1] whereas others perform SDPD as the initial treatment.[16] Considering its benignity, we recommend early SDPD because after two or three subdural taps, it becomes generally obvious that other treatments will be needed. We find it is nevertheless preferable to proceed with no less than two subdural taps before draining because initially the fluid is often too viscous, incurring the risk of catheter clogging but becomes thinner after a few taps. This contrasts with views of other authors who refute SDPD on the basis of its cost.[5,8] In our healthcare system, the cost of treatment only depends on the duration of hospital stay, and the shorter it is, the more cost efficient is the procedure. The SDPD is associated with a shorter hospital stay,[16] and we do not find any medical or economic benefit to delay it. In our series, however, the postoperative stay was lengthy in many cases because of legal inquiries related to suspected child abuse.

Surgical Technique of SDPD

Some authors use a low-pressure valve for SDPD,[1,2] just as we did at the beginning of our experience. Many of these valves became quickly clogged due to the high protein content of subdural fluid. Presently, we use a free shunt; it is soon disconnected from the CSF circulation after drainage because the subdural space is not an anatomical space. A minimal approach to the dural space through a coagulating puncture is enough to insert the subdural catheter with a curved introducer. This technique avoids breaching the subarachnoid space, which can cause shunt dependency. Although it has been reported that unilateral SDPD is efficient for bilateral SDH,[2,16] some patients with unilateral drainage have required a second operation for SDH on the other side.[6,16] It is well acknowledged that the density of the fluid collection is often different from one side to the other, as commonly shown by bilateral tapping and MR images (Fig. 3). This difference in fluid composition suggests the presence of a gradient from one side to the other. When the SDH is bilateral we prefer bilateral drainage because we think that it balances the pressure and avoids brains shifting. In theory, the two additional scalp incisions required by this technique bear a higher risk of infection; however, our study shows that the rate of postoperative infection is low. By contrast, the risk of catheter obstruction is a big concern and may be the basis for an additional argument in favor of bilateral drainage. We find it important to avoid the loss of fluid during insertion of the subdural catheters and to unclamp both cathe-

ters at the same time. At the time the SDPD unit is removed, the use of intraluminal coagulation to detach the catheter is essential to avoid subdural bleeding. We did not experience this complication in our series, but the risk should not be overlooked.[24]

Complications of SDPD

The complications of SDPD can be classified as early postoperative complications related to the technique, delayed complications related to the patient's clinical condition, and late complications related to the presence of the shunt material. Although most shunts were removed after a few months, we found it interesting to study outcomes of shunts left in place for a longer period, as was the rule at the beginning of the series, because the need for systematic shunt removal is not universally accepted.[16]

Infection is the most serious complication of SDPD. Early shunt infection is conditioned above all by surgical technique, as illustrated by improved infection rates during the last years of our study. Late-onset infection may be related in some cases to blood-borne pathogens, such as pneumococcus or *Haemophilus* species after airway infection, or *Staphylococcus* after skin infection (complicating chicken pox for instance).[3,15] Bowel perforation is another cause of sepsis and may occur early as well as late. Skin necrosis is an additional cause of infection,[18] and its occurrence has been associated with the use of reservoir catheters.[6]

Obstruction is the most common complication of SDPD[6] and can be an indication for revision of the SDPD or open surgery for membrane removal. The persistence of SDH after SDPD is favored by brain atrophy resulting from the initial damage.[22] In our experience, the severity of the initial presentation was highly correlated with shunt obstruction. In other series, a higher rate of obstruction can be ascribed to the use of valve-regulated shunts.[6] Although the occurrence of shunt migration may be as high as 8%,[6] our patients did not experience this complication. This may be due to the more complicated design of bilateral drainage or to the relatively short duration of drainage, time during which growth is not significant enough for the catheters to be displaced.

The incidence of shunt dependency is diversely appreciated: no case has been reported in a recent series,[6] but an earlier study found an incidence as high as 15%.[14] In our series, the incidence of shunt dependency was low and may be due to our technique of catheter introduction or to our policy of systematic SDPD removal after a few months. Because the majority of cases of hydrocephalus presented before removal of the SDPD unit, they are probably a form of posttraumatic hydrocephalus. In our practice, VP shunts are more frequently needed in older children with SDH or in children with nontraumatic SDH.

None of our patients experienced acute SDH after SDPD, as reported by other authors.[16] Because tearing of the cortical veins, a possible cause of the bleeding, could be caused by brain shift after unilateral drainage, this may provide the basis for another argument in favor of bilateral drainage.

Shunt Removal

Delayed complications associated with the presence of shunt material include bowel perforation, skin ulceration,[6] and blood-borne bacterial infection.[3,15,16] Delayed complications are time dependent, as suggested by data in Figs. 4 and 5. In addition, the presence of a peritoneal catheter complicates any further abdominal surgery. We experienced no complication related to SDPD removal, except three cases of posttraumatic hydrocephalus unmasked by SDPD removal. Systematic removal of SDPD is advocated by some authors[5,20,23,24] and opposed by others.[16,26] Shunt removal is a minimal painless operation performed during a short hospital stay. It is perceived by the child's parents as an important step toward definitive cure. Considering its low cost and risk of morbidity, as well as the risks associated with persistence of shunt material, we recommend that the SDPD unit be systematically removed.

Conclusions

We have reported on a large series of infants with traumatic SDH that was managed with a standardized protocol, namely bilateral drainage, placement of a free shunt, and systematic shunt removal. All these issues are debatable, and more results from comparable studies will be needed to conclude which surgical technique is the most appropriate.

Indications for SDPD have dramatically changed over the last decades, shifting from an innovative technique to a mainstream standard. This progress can be ascribed to better control of shunt complications in general and technical refinement of this particular technique. Although SDPD has now gained wide acceptance, large-scale reports of clinical results and estimations of its complication rate were previously lacking. The present report of 244 cases treated using this technique attempts to bridge that gap. Our opinion is that SDPD resolves the patient's problem quickly and that delaying surgery is of no benefit to the patient or the healthcare system. The complication rate of SDPD is acceptable, but can be lowered by meticulous technique and systematic removal of the drainage unit.

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