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Ventricular reservoirs and ventriculoperitoneal shunts for premature infants with posthemorrhagic hydrocephalus: an institutional experience

Clinical article

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Object. The aim of the study was to analyze the outcome of surgical treatment for posthemorrhagic hydrocephalus in premature infants.

Methods. From 1990 to 2006, 32 premature infants underwent surgical treatment for posthemorrhagic hydrocephalus, and their charts were retrospectively reviewed to analyze the complications and outcome with respect to shunt revisions. Multivariate analysis and time series were used to identify factors that influence the outcome in terms of shunt revisions.

Results. The mean gestational age was 27 ± 3.3 weeks, and mean birth weight was 1192 ± 660 g. Temporary reservoir placement was performed in 15 patients, while 17 underwent permanent CSF diversion with a ventriculoperitoneal (VP) shunt. In 2 patients, reservoir tapping alone was sufficient to halt the progression of hydrocephalus; 29 patients received VP shunts. The mean follow-up period was 37.3 months. The neonates who received VP shunts first were significantly older ($p = 0.02$) and heavier ($p = 0.04$) than those who initially underwent reservoir placement. Shunts were revised in 14 patients; 42% of patients in the reservoir group had their shunts revised, while 53% of infants who had initially received a VP shunt required a revision. The revision rate per patient in the reservoir group was half that in the direct VP shunt group ($p = 0.027$). No patient in the reservoir group had > 2 revisions. Shunt infections developed in 3 patients (10.3%), and 2 patients in the reservoir group died of nonneurological issues related to prematurity.

Conclusions. Birth weight and age are useful parameters in decision making. Preterm neonates with low birth weights benefit from initial CSF drainage procedures followed by permanent CSF diversion with respect to the number of shunt revisions. *(DOI: 10.3171/2008.11.PEDS0827)*

Key Words • neonate • posthemorrhagic hydrocephalus • reservoir • shunt revision • ventriculoperitoneal shunt

Intraventricular hemorrhage is a major complication of preterm birth that can cause severe disability. Fragile blood vessels in the germinal matrix below the ventricular lining and instability of blood flow to this highly vascular area are the mechanisms behind IVH.[22] Multiple blood clots may block the fourth ventricle outlet and impede the absorption of CSF across the arachnoid villi. Obstruction and impaired absorption of CSF will initially lead to progressive dilation of ventricles and subsequently to hydrocephalus with progressive enlargement of the head. The initial, reversible dilation is due to blood clots and the resulting production of TGFβ1, which is thought to be responsible for the production of extracellular matrix proteins around the brainstem and in the subarachnoid space.[25] Various treatment options have been proposed to manage posthemorrhagic hydrocephalus in preterm infants.[8,12–14,20,24,26,27] In this paper we present our experience with 32 infants who presented with neonatal posthemorrhagic hydrocephalus.

Abbreviations used in this paper: IVH = intraventricular hemorrhage; VP = ventriculoperitoneal.

Methods

From 1990 to 2006, a total of 32 neonates underwent surgical treatment for posthemorrhagic hydrocephalus at the Department of Neurosurgery of the Louisiana State University Health Sciences Center–Shreveport. The study was approved by the institutional review board. We retrospectively reviewed the medical records of these patients to analyze the outcome and complications of reservoir placement and permanent CSF diversion with a VP shunt. All premature infants were initially admitted to the neonatal intensive care unit, and cranial ultrasonography was used to diagnose periventricular–intraventricular hemorrhage (Fig. 1). Intracranial hemorrhage was graded according to Burstein et al.[2] All patients received initial placement of either a VP shunt (VP shunt group) or a ventricular reservoir (reservoir group). Our strategy was to perform intermittent reservoir tapping until the preterm infants were of appropriate weight; we then determined the need for permanent shunting on an individual basis. Serial tapping of the subcutaneous ventricular reservoir was performed for temporary drainage until conversion to a permanent VP shunt or resolution of hydrocephalus. The efficacy of reservoir tapping was judged by the reduction of head circumference, softening of the anterior fontanel, and reduction in ventricle size seen on cranial ultrasonography or CT scans. Commercially available software (SAS version 9.1.3) was used for statistical analysis, and a 5% level of significance was used for all statistical tests. The chi-square test was used to determine any relationship between the number of shunt revisions versus initial management, birth weight, and IVH grade. The 2-sample t-test (for unequal variances) was used to compare the 2 methods of initial treatment on the average number of shunt revisions performed and average age at first revision. The Wilcoxon rank-sum test was used to compare the 2 groups with respect to gestational age, birth weight, IVH grade, and number of infants with shunt revisions. Shunt survival plots for the second, third, and fourth revisions were generated using the Kaplan-Meier method of survival analysis.

Results

Thirty-two neonates with a mean gestational age of 27 ± 3.3 weeks (range 23–36 weeks) and a mean birthweight of 1192 ± 660 g were included in this study (Table 1). Intraventricular hemorrhage was classified as Grade III in 15 patients and Grade IV in 15 cases. In 2 cases we could not retrieve the documentation regarding the IVH grade. In 15 infants (46.8%), hydrocephalus was managed with reservoir placement, and 17 (53%) underwent permanent CSF shunting as the initial procedure. The infants who received VP shunts initially were significantly older ($p = 0.02$) and heavier ($p = 0.04$) than those who initially received reservoirs (Table 2). The mean age at reservoir placement was 39 days (range 9–84 days). In 2 patients (13.3%) reservoir tapping alone was sufficient to halt hydrocephalus progression (Fig. 2); no follow-up data were available in 1 patient. In the remaining 12 infants, permanent CSF diversion was necessary to halt the progression of hydrocephalus (Table 3).

Ventriculoperitoneal Shunt Placement

Twenty-nine patients (90%) underwent permanent CSF diversion procedures. This group included 12 with persistent hydrocephalus despite initial reservoir placement and 17 who received permanent VP shunts initially. The mean age at VP shunt placement was 103 days (range 7–344 days), and the mean age at which a reservoir was converted to a permanent shunt was 93 days (range 62–159 days).

Shunt Revisions

Shunts were revised in 14 (48.3%) of 29 patients; 5 (42%) of 12 infants in the reservoir group underwent revision, and 9 (53%) of 17 infants in the VP shunt group required revision surgery (Fig. 3). The maximum number of required shunt revisions was 4. No infant who underwent VP shunt placement subsequent to reservoir failure required > 2 revisions subsequent to reservoir failure, but this was not statistically significant compared to infants in the VP shunt group (Fig. 4). Although a greater proportion of infants had shunt revisions in the VP shunt group than in the reservoir group (9 vs 5 infants), this observation was not statistically significant ($p = 0.265$). In the VP shunt group, the total number of revisions was 22, and the average revision rate per patient was 2.4. In the reservoir group patients, the total number of revision surgeries was 6, and the average revision rate per patient was 1.2 (Table 4). The difference in revision rates per patient was statistically significant between the groups ($p = 0.027$). Infants who received VP shunts as the first treatment had a significantly higher average age at the first shunt revision than

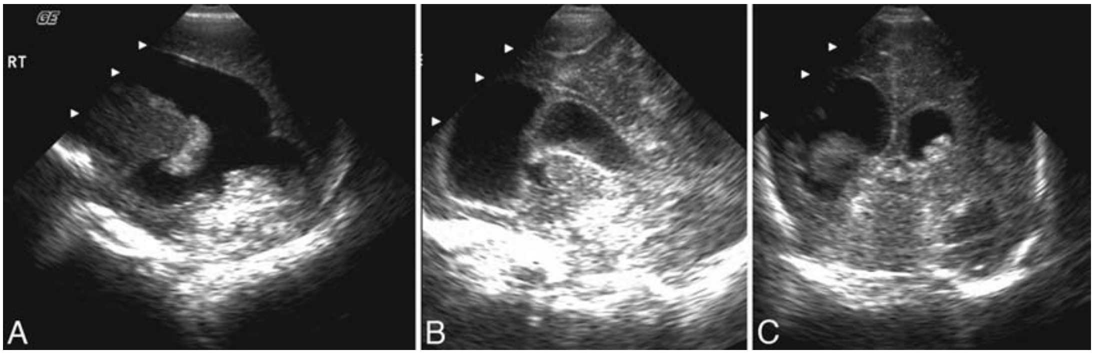

Fig. 1. Ultrasonography images obtained in a representative patient showing evidence of enlarged lateral ventricles. There is also evidence of a retracting clot in both ventricles. In this case, reservoir tapping alone was sufficient to halt the progression of hydrocephalus.

TABLE 1: Gestational age, birth weight, and IVH grades in all 32 patients*

Gestational Age (wks)	Birth Weight (kg)	IVH Grade	Other CNS Problems
29	1.33	III	
27	1.24	III	
NA	NA	NA	
29	1.4	IV	
24	0.74	III	
24	0.72	III	
30	1.58	IV	
29	1.43	IV	posterior fossa cyst & encephalomalacia
25	0.83	IV	
NA	NA	NA	encephalomalacia
25	0.86	III	
25	0.78	4	
27	1.4	III	
25	0.53	III	hypopituitarism & diabetes insipidus
23	0.71	IV	
31	1.62	III	
29	0.91	IV	
34	1.6	III	
24	0.68	III	
31	1.7	III	
26	0.8	IV	
24	0.82	IV	
24	0.63	IV	
26	0.77	IV	
27	1.21	IV	
31	2.09	III	hypoplastic corpus callosum
25	0.83	IV	periventricular leukomalacia
36	4	III	
29	1.13	IV	
26	1.16	III	
25	0.82	IV	
29	1.48	III	

* NA = not available.

those who underwent shunt placement after reservoir failure (p = 0.046). The 2 groups did not differ significantly in average age at the second shunt revision, and there was no statistical correlation between number of shunt revisions and birth weight (p = 0.469), or between IVH grade and the need for shunt revision (p = 0.456). Revision-free survival plots for the second, third, and fourth revisions were calculated according to the Kaplan-Meier method of survival analysis (Fig. 5). At the maximum follow-up of 96 months, 15.5, 31.0, and 41.3% of the 14 patients had not yet undergone a second, third, or fourth shunt revision, respectively (Table 5).

TABLE 2: Patient characteristics in 32 patients stratified by initial treatment*

Characteristic	Direct VP Shunt (17 patients)	Reservoir (15 patients)	p Value
gestational age (wks)	28.7 ± 3.7	25.8 ± 2.0	0.02†
no. w/o info	1	1	
birth weight (kg)	1.42 ± 0.81	0.94 ± 0.29	0.04†
no. w/ missing info	1	1	
IVH grade	3.4 ± 0.5	3.6 ± 0.5	0.15
no. w/ missing info	1	1	
no. w/ SRs (%)	9 (53)	5 (42)‡	0.26
no. w/ 3 or 4 SRs (%)	4 (25)	0 (0.0)	0.10
died (%)	0	2 (13.3)	0.21

* info = information; SR = shunt revision.
† Statistically significant.
‡ One patient was lost to follow-up and in 2 patients tapping alone was sufficient to halt the progression of hydrocephalus. Shunt revision percentages were calculated from the remaining 12 patients.

Surgical Complications

Two patients in the reservoir group died, and 1 other patient developed ventriculitis after reservoir placement. The cause of death was related to premature birth in both the cases. There were no deaths in the shunt group. Subdural hematomas developed in 2 patients (6.9%), and an epidural hematoma arose in 1 patient (3.4%) after shunt insertion; shunt infections developed in 3 patients (10.3%) (Table 6). Of those with shunt infections, 1 had an abdominal abscess, which led to the infection. A trapped occipital horn developed in 1 patient which required an additional shunt placement.

Discussion

Various treatment modalities have been suggested for posthemorrhagic hydrocephalus in preterm infants. These treatments include repeated lumbar punctures, serial ven-

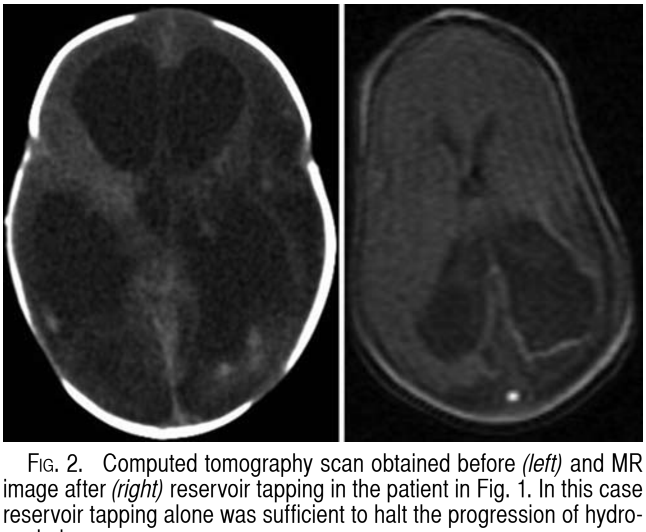

Fig. 2. Computed tomography scan obtained before *(left)* and MR image after *(right)* reservoir tapping in the patient in Fig. 1. In this case reservoir tapping alone was sufficient to halt the progression of hydrocephalus.

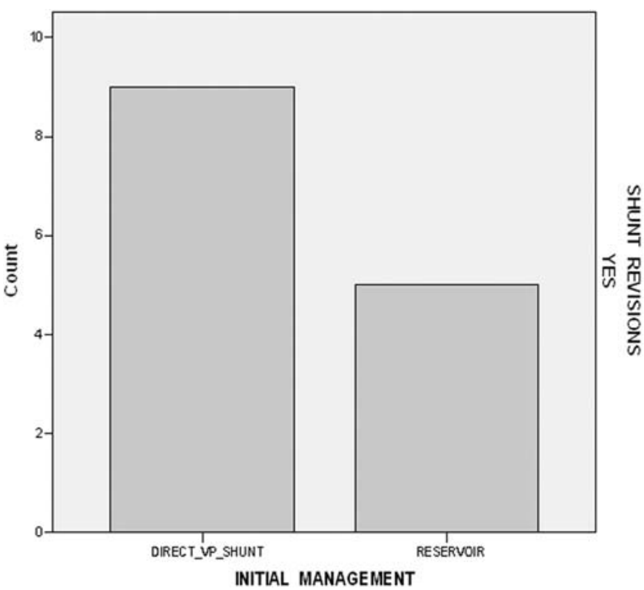

Fig. 3. Graph comparing the number of infants with shunt revisions in the VP shunt group (DIRECT_VP_SHUNT) with the ventricular reservoir placement group (RESERVOIR).

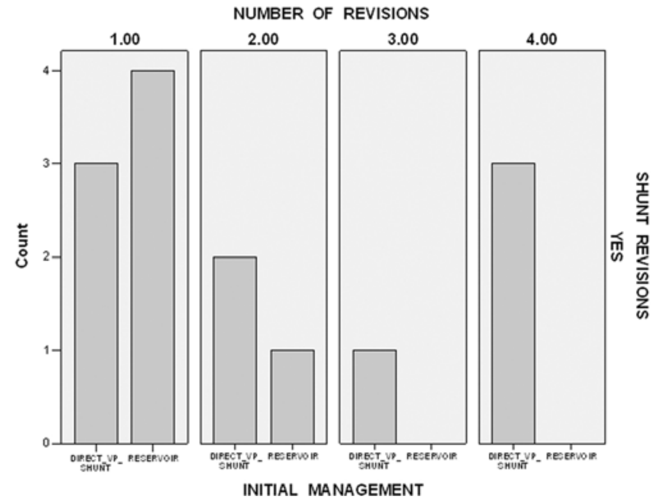

Fig. 4. Graph comparing the number of infants with 1, 2, 3, and 4 revisions between the 2 groups. It is very clear that > 2 revisions are absent in the infants who underwent initial ventricular reservoir placement. In the VP shunt group, the total numbers of revisions were 22 and the revision rate per patient was 2.4. In the reservoir group, the total number of revisions was 6, and the revision rate per patient was 1.2. This difference in revision rates per patient was statistically significant between the groups ($p = 0.027$).

tricular taps, diuretic therapy, streptokinase, and VP shunt placement. The efficacy of early lumbar punctures or ventricular taps have been evaluated in randomized trials and reviewed in the Cochrane Library.[23] There was no reduction in neurological disability or subsequent need for VP shunt placement in patients who received ventricular taps; moreover, there was an increased risk of infection. Repeated CSF drainage may be associated with hyponatremia.[13] Other treatments such as acetazolamide or furosemide cannot be recommended as therapy for posthemorrhagic hydrocephalus.[24] Intraventricular streptokinase therapy has been tried, but studies have shown that its use does not lead to a reduction in the need for shunt placement.[12] Other modalities such as endoscopic third ventriculostomy have been tried but with only limited success.[14] In a study conducted by the senior author (B.K.W.), ventriculosubgaleal shunts were tried as a temporary method of CSF diversion but were associated with a high infection rate.[27] The patients from this study are not included in the present study. The authors of other studies have found that the infection rate was 0% after subgaleal shunt placement,[9,15] while rates of 10% have also been documented.[17] In their recently pub-

TABLE 3: Summary of clinical characteristics of the patients in the reservoir group

Age at Reservoir Tapping (days)	Age at VP Shunt Conversion (days)	Outcome of Reservoir Tapping	Complications of Tapping	Died
24	—	successful		
63	141	unsuccessful	ventriculitis	
57	141	unsuccessful		
9	72	unsuccessful		
57	101	unsuccessful		yes
57	87	unsuccessful		
81	159	unsuccessful		
29	93	unsuccessful		
84*	unknown	unknown		
9	65	unsuccessful		
23	—	successful		yes
29	62	unsuccessful		
19	68	unsuccessful		
21	62	unsuccessful		
24	67	unsuccessful		

* No follow-up available.

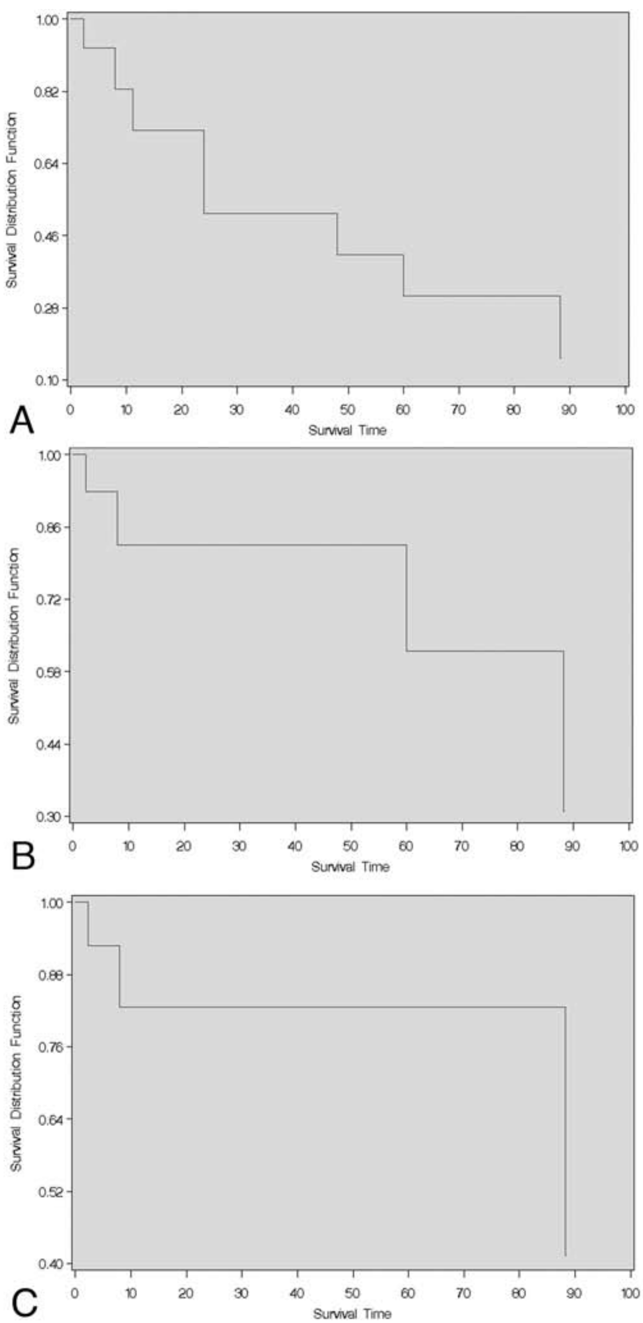

FIG. 5. Shunt survival at second (A), third (B), and fourth (C) revisions using the Kaplan-Meier method of survival analysis.

lished study, Whitelaw et al.[26] reported that drainage, irrigation, and fibrinolytic therapy (DRIFT) did not reduce the number of shunt surgeries or deaths in preterm infants with ventricular dilation after IVH compared to CSF tapping.

The only established treatment for persistent and progressive posthemorrhagic hydrocephalus with raised intracranial pressure is the surgical placement of a VP shunt.[6,21] In our study, reservoir placement successfully halted the progression of hydrocephalus in only 2 patients, while permanent shunts were needed in 90.6% of cases. Hudgins and colleagues[8] observed that in infants who received a ventricular access device, the rate of shunt placement was 88%.

TABLE 4: Comparison between 2 groups of infants with at least 1 revision treated with direct VP shunt and reservoir methods (mean ± SDs)*

Variable	Direct VP Shunt (9 patients)	Reservoir (5 patients)	p Value
no. of revisions	2.4 ± 1.3	1.2 ± 0.4	0.027†
age at 1st revision	34.7 ± 36.9	5.6 ± 2.3	0.046†
age at 2nd revision	34.2 ± 28.8	17.6 ± 9.1	0.26
no. missing	3	3	
age at 3rd revision	39.3 ± 41.8		
no. missing	5		
age at 4th revision	32.9 ± 4.8		
no. missing	6		

* All ages are given in months.
† Indicates statistical significance.

The timing of VP shunt placement is still controversial. In 1 study,[19] a higher complication rate was noted when a VP shunt was inserted prior to Day of Life 35. In our series only 5 patients had a shunt inserted prior to Day of Life 35, and only 1 had a complication (shunt infection). Some authors have suggested that rather than the timing of VP shunt placement, birth weight at the time of the permanent diversion procedure is more important.[3] Our strategy was to use serial ventricular reservoir tapping until preterm babies could gain weight, and VP shunts were subsequently placed if hydrocephalus persisted. Intermittent CSF drainage provided these premature infants with time to recover from the ventricular hemorrhage, gain weight, and clear the blood and protein elements from the CSF.[4] Kazan et al.[10] have studied the risk factors for requiring VP shunt placement. In their series, the severity of IVH was the important risk factor for requiring a VP shunt. These authors also reported that temporizing therapies used in the treatment of posthemorrhagic hydrocephalus were not significant risk factors for needing a VP shunt.

Overall 48% of infants had their shunts revised in the present series. Shunt blockage was an important reason for revision in this group of patients with posthemorrhagic hydrocephalus.[16] Revision rates of 20–50% are not uncommon in premature infants and revision rates as high as 68% have been reported in the literature.[1,3] In our series, birth weight and IVH grade had no influence on the shunt revision rates in the 2 groups of patients. We observed that more infants required shunt revisions when a VP shunt was

TABLE 5: Revision-free rates and median time (age) at second, third, and fourth shunt revisions in 14 infants with at least 1 revision

Revision No.	Revision-Free Rate (%)	Median Revision-Free Time (mos)	95% CI for Median (mos)
2	15.50	48.0	11.2–88.3
3	30.95	88.0	60–∞*
4	41.27	88.3	88.3–∞*

* ∞ = no upper limit calculated for the 95% CI.

TABLE 6: Summary of outcomes, revisions, and complications in infants who received VP shunts*

Age at VP Shunt Placement (days)	Shunt Problems	No. of SRs
30		0
90		4
immediately after birth		1
141		2
79		0
36		1
120		2
141		0
72		1
101		0
87	subdural hematoma (overdrainage)	1
243		3
159	shunt infection	1
93		0
277	trapped occipital horn	0
110		0
29		0
344		0
30		0
60		2
290		0
38	abdominal abscess w/ shunt infection	4
65	epidural hematoma	0
7		1
7	shunt infection	4
67		0
62		0
68		0
62	subdural hematoma	1

* There were no deaths in this group.

performed as the initial intervention. We also observed that initial therapy had a significant impact on the revision rates. There was a significant difference in the revision rate per patient in the VP shunt group compared to the reservoir group. A possible explanation could be that repeated drainage clears the blood products from the CSF, which might reduce subsequent shunt blockages.[4,7]

In the literature, the incidence of ventriculitis in patients with serial lumbar or ventricular tapping is 0–27%.[18,20] In our study the incidence of ventriculitis after ventriculostomy was 6.6% (1 case), which is comparable to the existing literature. In their series of 20 infants who underwent ventriculostomy, Heep and associates[4] noted infection in 1 patient. Hudgins and colleagues[8] noted an infection rate of 8% with the use of a ventricular access device. We did not notice any other complications such as skin breakdown or CSF leakage in our series. In the present study the incidence of shunt infection was 10.3% (3 patients). The numbers in our study are too small for any correlation between prior reservoir placement and subsequent shunt infections to be found. Hislop et al.[5] studied the outcomes in infants who received shunts for posthemorrhagic hydrocephalus and found that first shunt failure was significantly reduced with increased infant weight and lower protein levels at surgery. The clinical outcome in their study was correlated best with preoperative parenchymal brain lesions and was not related to shunt surgery or complications. Lin et al.[11] observed that adverse outcomes were statistically related to having > 4 shunt procedures and ventriculitis but were independent of maximum ICP or other perinatal factors.

In the present study, infants who initially underwent VP shunt placement were significantly older and heavier than those who initially received reservoirs. We believe that birth weight and age should be taken into account in treatment planning. A ventricular reservoir can be placed safely in preterm infants. We observed only 1 case of ventriculitis and none of our patients had complications like skin defects or CSF leaks. The 2 deaths observed in this group were related to prematurity. With respect to shunt revisions, infants who underwent reservoir tapping followed by VP shunt placement required significantly fewer revision surgeries per patient and fewer patients overall required shunt revisions. No baby in the reservoir group underwent > 2 shunt revision surgeries. A possible explanation for this finding could be that repeated drainage clears the blood products from the CSF, thus reducing subsequent shunt blockages.[7] Although the authors of the Cochrane database review on the subject[23] did not recommend lumbar or ventricular punctures as measures to reduce permanent hydrocephalus and need for shunt placement, the longer revision-free survival of infants with initial CSF drainage in the present study would suggest a positive perspective for safe CSF drainage procedure.

Conclusions

Birth weight and age should be taken into consideration in choosing a treatment strategy. Initial reservoir tapping of the CSF did not reduce the number of infants who required shunt surgery. Preterm babies with low birth weights benefitted from an initial ventricular CSF drainage procedure (drain placement) followed by more permanent CSF diversion (VP shunting). This strategy might also reduce the number of shunt revision surgeries in older infants and should be studied further in a large randomized patient population.

Disclaimer

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

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