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A multicenter retrospective comparison of conversion from temporary to permanent cerebrospinal fluid diversion in very low birth weight infants with posthemorrhagic hydrocephalus

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Abstract

Object—The purpose of this study was to define the incidence of permanent shunt placement and infection in patients who have undergone the 2 most commonly performed temporizing procedures for posthemorrhagic hydrocephalus (PHH) of prematurity: ventriculosubgaleal (VSG) shunt placement and ventricular reservoir placement for intermittent tapping.

Methods—The 4 centers of the Hydrocephalus Clinical Research Network participated in a retrospective chart review of infants with PHH who underwent treatment at each institution between 2001 and 2006. Patients were included if they had received a diagnosis of Grade 3 or 4 intraventricular hemorrhage, weighed < 1500 g at birth, and had received surgical intervention. The authors determined the incidence of conversion from a temporizing device to a permanent shunt, the incidence of CSF infection during temporization, and the 6-month CSF infection rate after permanent shunt placement.

Results—Thirty-one (86%) of 36 patients who received VSG shunts and 61 (69%) of 88 patients who received ventricular reservoirs received permanent CSF diversion with a shunt ($p = 0.05$). Five patients (14%) in the VSG shunt group had CSF infections during temporization, compared with 11 patients (13%) in the ventricular reservoir group ($p = 0.83$). The 6-month incidence of permanent shunt infection in the VSG shunt group was 16% (5 of 31), compared with 12% (7 of 61) in the

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reservoir placement group ($p = 0.65$). For the first 6 months after permanent shunt placement, infants with no preceding temporizing procedure had an infection rate of 5% (1 of 20 infants) and those who had undergone a temporizing procedure had an infection rate of 13% (12 of 92; $p = 0.45$).

Conclusions—The use of intermittent tapping of ventricular reservoirs in this population appears to lead to a lower incidence of permanent shunt placement than the use of VSG shunts. The incidence of infection during temporization and for the initial 6 months after conversion appears comparable for both groups. The apparent difference identified in this pilot study requires confirmation in a more rigorous study.

Keywords

hydrocephalus; premature birth; intraventricular hemorrhage

High grade PHH in premature, low birth weight infants remains one of the most common causes of hydrocephalus necessitating shunt placement. Hydrocephalus affects 1 in every 500 children in the general population, with nearly half of affected children born prematurely.¹³ A recent study by the National Institute of Child Health and Human Development reported a 36% incidence of Grade 3 or 4 IVH in the postsurfactant era.⁷ The incidence of IVH in infants of low birth weight approaches 50%.^{6,26} In 2 commonly referenced studies of patients undergoing surgical temporization for symptomatic hydrocephalus due to IVH of prematurity, 57 and 85% of the survivors required permanent shunt placement.^{9,11} The authors of recent studies have suggested that infants with PHH and extremely low birth weights who require permanent shunt placement are at a greater risk for adverse neurodevelopmental and growth outcomes compared with a similar cohort of children who did not receive shunts.¹

Numerous temporary CSF diversion methods are used in the initial treatment of PHH in children born prematurely. These children often do not tolerate the placement of a permanent VP shunt system as the initial procedure because of blood within the ventricular system and the high likelihood of valve mechanism obstruction caused by blood breakdown products. Many children are physically too small to tolerate the valve and shunt tubing itself, and are prone to skin breakdown and infection. Inability to absorb CSF volume distally within the peritoneum may also contribute to permanent shunt failure in this population. Necrotizing enterocolitis precludes the diversion of CSF into the peritoneum in many patients. Therefore, temporary CSF diversion is often required while awaiting improvement of either the proximal or distal environment for permanent shunt placement. Alternatively, the child may not need permanent CSF diversion if the normal absorptive process recovers during temporization. Traditionally, temporizing treatment has ranged from the medical (including acetazolamide or furosemide therapy) to the more invasive (including intermittent lumbar punctures or transfontanelle ventricular taps). The authors of published scientific reviews have suggested that these approaches are not successful in preventing permanent shunt placement.^{22,23}

Criteria for treatment vary by surgeon and institution. The 2 most common operations for the temporary treatment of PHH are: 1) VSG shunt placement, in which the CSF is shunted into the subgaleal space of the scalp and absorbed into the bloodstream; and 2) placement of a ventricular reservoir for intermittent tapping. The incidence of permanent shunt placement after these procedures is poorly defined. The purpose of the present study, conducted across 4 HCRN centers, was to investigate the incidence of conversion to a permanent shunt, and the rate of infection after these commonly performed temporizing procedures for PHH in very low birth weight infants.

Methods

We conducted a multicenter retrospective study in the HCRN. Participating HCRN centers included the Children's Hospital of Alabama in Birmingham, Primary Children's Medical Center in Salt Lake City, Texas Children's Hospital in Houston, and the Hospital for Sick Children in Toronto. The protocol was submitted and approved by each institution: University of Alabama at Birmingham Institutional Review Board approval number X070320003; the Baylor College of Medicine Institutional Review Board approval number H-21400; the Hospital for Sick Children Research Ethics Board approval number 1000011020; and the University of Utah Institutional Review Board approval number 00023423. No informed consent was required, and each institution granted a waiver of consent. Where appropriate, a Health Insurance Portability and Accountability Act (HIPAA) waiver was also granted.

An electronic database search was conducted at each institution to identify all children diagnosed with IVH of prematurity. Data collected were then complemented by a medical record chart review of patients who met inclusion criteria: 1) birth date during the years of 2001–2006; 2) diagnosis of Grade 3 or 4 IVH; 3) birth weight < 1500 g; and 4) surgical intervention for hydrocephalus with either a temporizing mechanism or permanent shunt placement.

Patients were stratified by surgical intervention to compare conversion rates between sites and initial temporizing mechanisms. We also evaluated this cohort to compare the incidence of infection during temporization and in the initial 6 months after permanent shunt placement among the sites. Cerebrospinal fluid infection was defined as either: 1) identification of organisms on culture or gram stain of CSF, wound swab, and/or pseudocyst fluid; 2) shunt erosion through skin (visible hardware); or 3) the presence of an abdominal pseudocyst (even without a positive culture). Patients who died or may have received care at an outside facility were not included in our cohort and analysis.

Two commercially available software programs (Analyze-it for Microsoft Excel and SAS statistical software, SAS Institute, Inc.) were used to analyze our data, and a normal distribution was assumed. Chi-square calculations were performed, and a probability value < 0.05 indicated statistical significance. For calculations with < 5 observations, the Fisher exact test was used.

Results

Based on our review utilizing the inclusion criteria previously listed, 364 infants were included in our cohort. Of these, 147 patients (40%) underwent surgical interventions for hydrocephalus (Table 1). Among those who required surgical intervention, 127 (86%) underwent an initial temporizing mechanism, and in 20 patients (14%) the initial treatment was permanent CSF shunt placement (Table 2). At 3 of the 4 HCRN centers (Sites A–C), 1 surgical intervention was used over the other. The fourth center (Site D) showed a proclivity for initial permanent shunt placement over temporization. The proportion of patients who underwent permanent CSF diversion after VSG shunt or reservoir placement was 31 (86%) of 36, and 61 (69%) of 88, respectively ($p = 0.05$; Table 3).

The overall incidence of subgaleal shunt and reservoir infections was 14% (5 of 36), and 13% (11 of 88), respectively ($p = 0.83$; Table 4). For the initial 6 months after permanent shunt placement, infants with no preceding temporizing procedure had an infection rate of 5% (1 of 20), and those with a preceding temporizing procedure had an infection rate of 13% (12 of 92; $p = 0.45$; Table 5). Within the first 6 months, infections occurred in 16% of infants whose temporizing procedure was VSG shunt placement, and 12% of those who initially received reservoir placement ($p = 0.65$; Table 5). No statistically significant difference was found in infection rates.

Discussion

Little is truly understood with regard to maximizing existing CSF absorptive pathway function in hydrocephalus, particularly in the setting of PHH. It would be logical to hypothesize that the method of initial surgical treatment for PHH may be related to the rate of conversion to permanent shunt placement, shunt failure, and shunt infection. The literature suggests that shunts have a median survival time of 2–7 years, and that PHH is associated with an increased risk of shunt failure.^{5,10,12,16,20} Posthemorrhagic hydrocephalus remains one of the most common causes of childhood hydrocephalus. Intraventricular hemorrhage causing ventricular dilation (Grade 3) or ventricular dilation with involvement of the adjacent parenchyma (Grade 4) is more likely to cause obstruction of the absorptive pathways than a germinal matrix hemorrhage (Grade 1) or an IVH not causing ventricular dilation (Grade 2). Efforts to better understand disruptions in CSF absorptive pathways are necessary if any reduction in the hydrocephalus burden in children is to be made. Little is known concerning the relationship of clot size, ventricular dilation, and hemorrhagic breakdown products to the method of successful surgical intervention.

Ventriculosubgaleal shunts have been well described in the literature. A 10-year series of 173 patients from the University of Iowa in 1977 is the largest and earliest report found.¹⁵ Rahman and colleagues¹⁷ reported on 17 infants with PHH in whom initial treatment consisted of serial lumbar punctures. Fifteen of their patients went on to require subgaleal shunts without complications, and 3 did not require conversion to permanent shunting. Subgaleal shunts can be revised in situations where the subgaleal pocket is contracting but the consistency of the CSF is such that residual debris is likely to occlude a permanent shunt system. With the patient in a state of general anesthesia, the skin incision is reopened and the subgaleal pocket reestablished. The average length of survival of the initial VSG shunt is 37 days, 32 days for the first revision, and 20 days for a rare second revision.¹⁹ Benefits of this method of temporary CSF diversion are believed to include: 1) not requiring intermittent transcutaneous access to a reservoir, with the associated risk of skin contamination and device infection; 2) maintenance of a closed system in which fluid and electrolytes are not lost as with either an external ventricular drain or intermittent tapping, thereby reducing the need for replacement; 3) a theorized mild back-pressure from the subgaleal space that maintains a challenging force for the absorptive pathways to overcome in an effort to “kick start” normal function; and 4) the potential for earlier discharge home in lieu of continued hospitalization for tapping and electrolyte management.

The use of a subcutaneously implanted ventricular access reservoir as a temporizing treatment for PHH has been well described since at least the 1980s.^{4,11} The procedure is technically relatively simple, and allows for controlled transcutaneous CSF withdrawal that can be performed on an as-needed basis, usually guided by clinical parameters. The reservoir has some distinct advantages over other means of intermittent CSF withdrawal such as repeated lumbar puncture (which frequently yields only a small volume of CSF) and repeated transcortical ventricle puncture (with its risk of needle-track injuries).²¹ The most worrisome complications of using a reservoir are CSF leakage, infection, and possible skin breakdown (up to 22% incidence).^{2,14,18} Intermittent CSF removal from the reservoir is thought to promote a return to normal CSF absorption in a subgroup of children with PHH, thus avoiding a permanent VP shunt. This effect might be the result of the continued challenge to the CSF absorption system by the CSF that is allowed to build up prior to artificial withdrawal; it might also be aided by the removal of hemorrhagic debris from the CSF. The incidence of shunt independence is not well documented. Although some authors have suggested an incidence of ~20–30%, this is probably related to multiple factors, including treatment selection criteria.^{3,14,18}

Alternative methods of attempting to temporize or treat PHH certainly exist. Surgeons at many medical centers routinely perform serial lumbar punctures or serial direct ventricular taps to control head size. In a Cochrane review published in 2001, Whitelaw²² concluded that “early repeated CSF tapping cannot be recommended for neonates at risk of, or actually developing, post-hemorrhagic hydrocephalus,” because there was no statistically significant decrease in shunt placement, death, disability, or multiple disability, and there was an increase in the risk of CSF infection compared with conservative treatment. Additionally, in a later Cochrane review, Whitelaw et al.²³ concluded that neither acetazolamide nor furosemide treatment was effective or safe, and could not be recommended. Much hope was placed in intraventricular fibrinolytics for the reduction of clot burden in the hope of promoting normal CSF circulation.^{8,25} In 2007, the Cochrane Collaboration published Whitelaw and Odd’s study²⁴ advising against the use of intraventricular streptokinase in newborns with IVH, as the outcome determinants of death and shunt dependence were similar to controls. Temporization of PHH utilizing some means of surgical CSF diversion therefore remains the mainstay of treatment.

It is important to note the limitations inherent in any retrospective patient review. Each institution had different criteria for initial treatment, including initial head size and rate of growth, ventriculomegaly, rate of change in ventricular size, and symptoms necessary for treatment such as apnea, bradycardia, size and turgor of anterior fontanel, and degree of separation of skull sutures. The criteria for using a temporizing measure or permanent shunt placement were also not standardized. In many instances, variables such as: 1) adequate infant weight for permanent shunt placement; 2) radiographic criteria for blood products within the ventricle on imaging necessary for permanent placement; and 3) what defines the need to temporize versus implant a permanent shunt defied a clear definition. Determinants of when to convert from temporization (either VSG shunt or reservoir) to formal shunt placement based on these same parameters were disparate as well. In some cases, variability in criteria related to the decision to treat, the decision to temporize versus place a shunt, and the decision to convert to a shunt existed between institutions and even among surgeons at the same institution. These variables are the subject of a further HCRN study currently under way.

Of the total cohort, 40% underwent surgery, whether for a temporizing measure or permanent shunt placement. There were fewer surgically treated patients overall at Site D, and when electing to treat, physicians at this institution more frequently performed permanent shunt placement than at other interventions. Two centers only performed temporization. These variations probably represent institutional, regional, and cultural bias toward or against treatment. The study cohort had a higher incidence of conversion to a VP shunt from VSG shunt than from a reservoir. This finding may identify an inherent benefit incurred in the reservoir group by an intermittent challenge to CSF absorption. Notably, however, the conversion of a reservoir to a VP shunt at Site B was < 50% in contrast to 100% at Site C. Site A, mainly a VSG shunt site, had a conversion incidence more similar to that of Site C for reservoir conversion. It is therefore likely that the variation in decision to treat, temporize, or convert detailed above may explain at least some of the differences among sites.

Conversely, patients identified as having an infection of either the temporary diversion device or the permanent shunt within the first 6 months after conversion were defined similarly across centers and surgeons. There were no statistically significant differences identified in any of the infection rates. Anecdotally, we believed that the presence of a temporization device made an individual patient more likely to have an infection within the initial 6 months after permanent shunt placement. Despite the numerical difference of 5 versus 13%, this did not bear out statistically, nor did our concerns over a potential increase in infection incidence with repetitive skin violation from repeated reservoir tapping.

Because of the variation by surgeon and center, the HCRN is designing a prospective cohort study in which criteria for 1) decision to treat, 2) decision to temporize versus place a shunt, and 3) decision to convert to a permanent shunt will be standardized across centers and surgeons within the HCRN. Following this prospective study, information gained will help determine whether a randomized controlled trial is necessary, and will assist with its successful design and implementation. We remind readers that until the time of the publication of the results of any additional future studies, the results reported here should be considered preliminary. Further study is worth pursuing, but at present the choice of surgical treatment that leads to a lower incidence of permanent shunt placement and infection in premature infants remains unclear.

Conclusions

The use of intermittent tapping of ventricular reservoirs in the treatment of PHH appeared to have a lower incidence to permanent shunt placement afterwards than VSG shunt placement in this retrospective study. There was no discernible difference in infection rates either during temporization or in the initial 6 months of permanent CSF diversion. Fundamental differences in key management decisions require standardization so that a definitive study can address the question of whether intermittent tapping of ventricular reservoirs is superior to VSG shunt placement as a temporizing procedure.

Abbreviations used in this paper

HCRN	Hydrocephalus Clinical Research Network
IVH	intraventricular hemorrhage
PHH	posthemorrhagic hydrocephalus
VP	ventriculoperitoneal
VSG	ventriculosubgaleal.

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TABLE 1

Study population by site and surgical status

Infant Characteristic *	Site A	Site B	Site C	Site D	Total Patients
met inclusion criteria *	77	129	70	88	364
did not undergo op for hydrocephalus (%)	40 (52)	76 (59)	31 (44)	70 (80)	217 (60)
underwent op for hydro- cepalus (%)	37 (48)	53 (41)	39 (56)	18 (20)	147 (40)

* Inclusion criteria were a diagnosis of Grade 3 or 4 IVH and birth weight < 1500 g.

TABLE 2
Type of initial surgical intervention by site in the 147 patients who underwent surgery for hydrocephalus*

Initial Surgical Intervention	Site (no. of patients)					Total (147)
	A (37)	B (53)	C (39)	D (18)		
VP shunt placement (%)	7 (19)	0 (0)	0 (0)	13 (72)		20 (14)
temporizing procedure (%)	30 (81)	53 (100)	39 (100)	5 (28)		127 (86)
VSG shunt reservoir	30 (81)	3 (6)	0	3 (17)		36 (24)
EVD	0	47 (89)	39 (100)	2 (11)		88 (60)
	0	3 (6)	0	0		3 (2)

* EVD = external ventricular drain.

TABLE 3
Permanent shunt placement after initial temporizing procedure by site in 124 patients

Temporizing Procedure	Site (no. of patients)				Total (124)
	A (30)	B (50)*	C (39)	D (5)	
VSG shunt	30	3	0	3	36
subsequent permanent VP placement	28	2	0	1	31 (86%)
reservoir	0	47	39	2	88
subsequent permanent VP placement	0	20	39	2	61 (69%)

* The 3 infants at Site B who underwent EVD placement for initial temporization are excluded. All 3 went on to receive permanent CSF diversion with VP shunt placement.

TABLE 4

Number of infections after initial temporizing procedure stratified by site

Parameter	Site (no. of patients)				Total (124)*
	A (30)	B (50)*	C (39)	D (5)	
no. of VSG shunts placed	30	3	0	3	36
no. of infected VSG shunts (%)	4 (13)	1 (33)	0	0	5 (14)
no. of reservoirs placed	0	47	39	2	88
no. of infected reservoirs (%)	0	4 (9)	7 (18)	0	11 (13)

* The 3 infants at Site B who underwent initial temporization with EVD are excluded. None had a documented CSF or device infection during temporization.

TABLE 5

Infection rates within 6 months of permanent shunt placement, stratified by initial surgical intervention and clinical site in 112 patients*

Surgical Intervention Before VP Shunt	Site (no. of patients)				Total
	A (35)	B (22) [†]	C (39)	D (16)	
no temporizing procedure	0/7	0/0	0/0	1/13	1/20 (5%)
temporizing procedure	4/28	5/22	3/39	0/3	12/92 (13%)
VSG shunt	4/28	1/2	0/0	0/1	5/31 (16%)
reservoir	0/0	4/20	3/39	0/2	7/61 (12%)
total	4/35 (11%)	5/22 (23%)	3/39 (8%)	1/16 (6%)	13/112 (12%)

* Data are displayed as number of patients with VP shunt infections 6 months after placement/number of patients with the specified temporizing procedure.

[†] The 3 patients at Site B who underwent initial temporization with an EVD prior to permanent shunt placement were excluded. None had a documented CSF or device infection within the first 6 months after permanent shunt placement.