A Cost-effectiveness Analysis of Endoscopic Third Ventriculostomy

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OBJECTIVE: Endoscopic third ventriculostomy (ETV) is currently the principal alternative to cerebrospinal fluid shunt placement in the management of pediatric hydrocephalus. Cost-effectiveness analysis can help determine the optimal strategy for integrating these different approaches.

METHODS: All patients (n = 28) who underwent ETV at British Columbia's Children's Hospital between 1989 and 1998 were matched for age, pathogenesis, and number of previous shunt procedures, with patients treated with cerebrospinal fluid shunts. To perform a cost-effectiveness analysis, hydrocephalus-related resource consumption and outcome (determined as the number of hydrocephalus treatment-free days during follow-up) were then retrospectively identified. Cost data were linked to resource use to provide a total cost for all resources used. Costs and outcomes were discounted annually at 5% by standard economic analysis methods.

RESULTS: Twenty-four of 28 ETV patients had obstructive hydrocephalus. Over equivalent follow-up periods (median, 35 mo), the ETV success rate (defined by need for reoperation) was 54%. One hydrocephalus-related death and one hemiparesis occurred in the ETV group. No permanent procedure-related morbidity or mortality was seen in the shunt group. The cost/effect ratios for the two groups were similar. The additional incremental resource use by the shunt group included six readmissions and eight reoperations. ETV mean costs per patient were $10,570 ± $7628, versus $10,922 ± $8722 for the shunt group (Canadian dollars for the year 2000). Costs accrued more quickly for the shunt group as time passed. The additional incremental outcome benefit to the endoscopy group was 86 treatment-free days (3.07 d per patient [95% confidence interval, −7.56 to 13.70 d]). Neither of these differences was statistically significant.

CONCLUSION: In this matched cohort, ETV was not significantly less costly or more effective over a median 35 months of follow-up, with a 54% initial ETV success rate, even before the additional morbidity and mortality encountered were taken into account. The time course for the accrued costs suggests that a larger cohort, longer follow-up, or higher success rates are needed to demonstrate the cost-effectiveness of this therapy.

KEY WORDS: Cost-effectiveness analysis, Cerebrospinal fluid shunt, Endoscopic third ventriculostomy, Hydrocephalus, Medical economics

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Endoscopic third ventriculostomy (ETV) is the principal alternative to cerebrospinal fluid (CSF) shunt placement in the treatment of hydrocephalus (4, 8, 15, 16, 21, 26, 27). The procedure has been advocated to avoid shunt placement in obstructive hydrocephalus for some time, but more recently, advocates have argued for the inclusion of patients with communicating hydrocephalus of various causes (6, 9). Precise indications for this procedure remain somewhat elusive, and considerable variability exists in self-reported practice patterns (17). When the procedure is successful, the subsequent risks of CSF shunt infection and malfunction are avoided. Even in experienced hands, however, the surgical risks of ETV are greater than those of routine shunt placement. Even with careful patient selection, this therapy will fail in a certain percentage of patients undergoing ETV, and these patients will still require shunt placement. A trade-off thus exists between an increased initial risk of complications and possible need for subsequent shunt placement and the long-

term benefits of shunt independence. These trade-offs are also apparent in considering the resources necessary to provide care along these two pathways. Patients undergoing ETV could potentially consume more resources initially because of costs of the neuroendoscope, additional days of hospitalization for evaluation, and possible shunt placement after ETV failure. This would be balanced against the long-term savings associated with avoiding subsequent shunt-related admissions. To address this question, we performed a cost-effectiveness analysis of a matched cohort of children undergoing either ETV or CSF shunt placement for the treatment of hydrocephalus in an attempt to determine whether ETV is indeed a cost-effective alternative to shunt placement.

Cost-effectiveness analysis seeks to compare the ratio of the costs of a treatment with the outcome for a common measure of effect between two different therapies. First, resource use for the different therapy arms must be determined from a specific perspective (e.g., patient, third-party payer, society as a whole), and a monetary cost must be determined for each of the resources used. Second, a common measure of effectiveness must be found and measured for each of the therapy arms. When costs and outcome events occur at different points over time, an adjustment that recognizes a preference for immediate benefits and deferred costs is usually made by applying a discount to future costs and benefits. Finally, the two therapy groups are compared by use of the ratios of cost to outcomes. A therapy may be dominant that is both less costly and associated with a better outcome, or an incremental additional cost may be associated with an improved outcome for one or another of the therapies (12).

PATIENTS AND METHODS

We conducted a case-control analysis of the treatment of all patients undergoing ETV at British Columbia's Children's Hospital, Vancouver, BC, Canada, between 1989 and 1998. To compare their costs and outcomes with those seen in the shunt treatment of hydrocephalus, we matched the ETV patients with a control group of children treated with shunts. To control for other possible influences on outcome other than the procedure of interest, the groups were matched by the pathogenesis of hydrocephalus and the patient's age at the time of the qualifying ETV or shunt placement (elsewhere referred to as the index procedure). In addition, as a marker for the complexity of the hydrocephalus in those patients undergoing ETV instead of a shunt revision, we matched patients for the number of total hydrocephalus-related procedures (excluding reservoirs or external ventricular drains) performed before the index procedure. The matching process was accomplished by use of a computerized practice database and was completed before any review of charts to determine either the costs or outcomes.

We examined hospital admissions, emergency room visits, and office visits. For each of these encounters, we tabulated the number of imaging studies performed, including plain x-ray, computed tomographic (CT) scanning, magnetic resonance imaging, and ultrasound studies. For hospital admissions, we recorded the length and location of the patient's stay and the use and duration of intravenously administered antibiotics. We evaluated operative events for their duration and the type of CSF shunt hardware or ventriculoscope used. We included only resource consumption that was related to hydrocephalus. For example, if a patient with a brain tumor was admitted for chemotherapy, this encounter was not included. However, if the same patient visited the emergency room for vomiting and a head CT scan was obtained to check ventricular size, this emergency room encounter was included, although the subsequent admission for dehydration after a negative shunt evaluation was not. Case and control patients were followed up for equivalent periods by limiting consideration to the point of shorter follow-up between the pair, so that each patient had equal exposure in the combined cohort. In determining resource use, the retrospective nature of the study limited our perspective to that of a third-party payer. We focused on hospital and physician resource use and could not consider items such as out-of-pocket family expenses or changes in parental productivity.

Cost-effectiveness analysis requires that the outcomes of the therapies have a common unit of measure. We measured the effects of therapy in terms of days free of the hydrocephalus treatment. This was calculated as the total days of follow-up, less time spent hospitalized for hydrocephalus-related treatment, and less a 14-day addition for each hospital admission to account for the impact of the prehospitalization illness and postdischarge recovery time. Complications of therapy that would not otherwise be apparent in a simple accounting of the duration of illness were recorded separately.

Unit costs for resources were drawn from several sources, including data provided by the British Columbia's Children's Hospital Health Services Study Unit, as well as the University of Michigan Health Care System's Clinical Information and Decision Support Service, by use of the TSI Costing System (Transition Systems, Inc., Boston, MA) (24). Professional fees were taken from both the Canadian published fee schedule for the Medical Services Commission: British Columbia (20) and similar private fee schedules from the United States that were modified to account for likely reimbursement amounts, given our choice of third-party payer perspective. A range of cost estimates was developed by contributions from both Canadian and United States data sources. This cost range was used to assess the sensitivity of the study conclusions to the specifics of the cost data. For the Canadian data set, costs for head CT scans and magnetic resonance imaging studies were calculated as a capital cost (initial outlay and maintenance/[service life $\times$ studies/yr]) + labor and nonlabor costs. In addition, we assumed that about one-third of these studies would require some form of sedation. We calculated the costs of neuroendoscope use on a similar basis. Operative time, emergency room costs, hospital day costs, and intensive care unit costs were based on yearly expenses, both direct and indirect, divided by the number of patient-days per year, but do not include capital costs. For hardware costs, we used the

actual charges incurred by the hospital for the items. For the United States data, the TSI cost system combines both fixed and variable direct cost (based on assigned relative value units) as well as apportioned indirect costs for overhead departments. For clarity, all dollar amounts are reported in Canadian dollars for the year 2000. We discounted both costs and effects at a rate of 5% annually as they accrued to account for the time preference for immediate benefits and delayed costs as opposed to immediate costs and delayed benefits.

Data were summarized with descriptive measures. Mean data were compared by Student's *t* test. A cost model was developed that used the cohort's resource use pattern over time to evaluate the effect of changes in the success rate of ETV on the cost stream over time. Tabulation and statistical comparisons were performed with Microsoft Excel (Microsoft Corp., Redmond, WA) and SPSS software (SPSS, Inc., Chicago, IL).

RESULTS

Between 1989 and 1998, 28 patients underwent 29 ETV procedures, with all but 5 of these undergoing the procedure in the last 3 years of this period. By use of the practice database, 28 patients treated for hydrocephalus with CSF shunts could be identified to match the 28 patients undergoing ETV placement. As intended, the two groups are comparable for the matched factors of pathogenesis of hydrocephalus, age, and number of previous shunt procedures performed. The choice of endoscopic versus shunt treatment in individual cases seemed to be determined by the prevailing practice pattern of the time, with most of the shunt patients in the cohort being treated in the 1980s, before renewed interest in third ventriculostomy. *Table 1* details the features of the case and control patients. Twenty-one of 28 patients in each group were undergoing their first procedure for hydrocephalus, excluding such temporary measures as external drainage. The remainder had undergone from 3 to 10 procedures before the index third ventriculostomy or shunt procedure. Twenty-four of 28 patients in the ETV group had obstructive hydrocephalus as a result of either aqueductal stenosis or lesions obstructing the aqueduct or fourth ventricle. The median follow-up period was 34.7 months (range, 87 d to 6 yr). Five patients in the ETV group died, four of causes unrelated to their hydrocephalus treatment. Excluding these patients, all but one had more than 2 years of follow-up. One patient in the shunt group died from causes unrelated to hydrocephalus during the follow-up period.

Among ETV patients, the procedural success rate, as defined by the avoidance of either repeat third ventriculostomy or shunt placement, was 54%. One patient in whom the procedure initially failed underwent a successful repeat ETV 3 weeks after the initial procedure and thereafter remained shunt-free. Two patients with meningomyelocele and two with meningitis as the cause of hydrocephalus underwent the procedure. Of these, only one of the meningomyelocele patients was able to remain shunt-free. Ten of 13 ETV failures occurred within 6 months. The latest failure, occurring at 25 months after the initial procedure, was associated with the patient's death and is discussed more fully below. *Figure 1*, a Kaplan-Meier survival plot, demonstrates the hazard of first-procedure failure for both the ETV and shunt groups, considering all available follow-up information, without limiting consideration to the point of shorter follow-up between the matched pairs.

Resource use during the hospitalization for the index procedure was higher in the ETV group (*Table 2*). The ETV group had longer length of stay (4.8 $\pm$ 6.0 versus 3.8 $\pm$ 2.4 d [mean $\pm$ SD]), required more operative time (2:20 h $\pm$ 48 min versus 1:35 h $\pm$ 22 min), and underwent more reoperations (4 versus 1) than the shunt group. A reusable neuroendoscope was typically used, and almost all patients were managed on the ward after surgery, most without a ventriculostomy catheter or intracranial pressure monitor.

During the subsequent matched follow-up periods, the resource use of the shunt group slightly exceeded that of the ETV group. During the median follow-up of 34 months, the 28 shunt group patients required more readmissions (22 versus 16), with a longer length of stay (4.1 $\pm$ 3.9 versus 3.38 $\pm$ 2.3 d), including greater use of the intensive care unit (7 versus 1 d). The increased length of stay in the shunt cohort could be fully explained by hospitalizations required to treat two shunt infections that occurred in this group and did not appear to represent a confounding change in practice patterns. *Table 2* further details aspects of the cohorts' resource consumption.

Treatment complications occurred in two patients in the ETV group. The first of these was a persistent, if mild, hemiparesis that occurred in a Pair 10 patient after the performance of an otherwise successful ETV. A postoperative head CT scan did not show a hemorrhage. The second complication occurred in a Pair 7 patient, a 12-year-old child with aqueductal stenosis who initially presented with headaches, nausea, and vomiting and a new sixth nerve palsy. Three months after the patient underwent an apparently successful ETV, a head CT scan demonstrated unequivocal reduction in the size of his ventricles. He became asymptomatic after ETV and remained so for 18 months but was then lost to our follow-up. He presented elsewhere at 25 months after ETV, was obtunded, and subsequently died. At autopsy, he was noted to have massive hydrocephalus, and the third ventricular fenestration was found to be closed.

Analysis of the cost data allowed us to generate low and high estimates for the dollar cost for particular resource uses (*Table 3*). These values do not always represent a Canadian versus United States cost experience, but rather a mix of the high- and low-end estimates we identified. For many items, such as hospital day costs, a range of potential figures was available that depended, in the TSI system, on patient acuity. Given that acuity data were not available for patients in our cohort, we chose an acuity representing the lower 33% of the cost range.

Combining the resource consumption with the assigned costs, we calculated the total and average costs for the cohort

TABLE 1. Cohort of matched endoscopic third ventriculostomy and shunt patients

Pair no.	Endoscopic third ventriculostomy			Cerebrospinal fluid shunt placement		
	Pathogenesis	No. of prior procedures	Age[a] (yr)	Pathogenesis	No. of prior procedures	Age[a] (yr)
1	Aqueductal stenosis	0	0.19	Aqueductal stenosis	0	0.02
2	Aqueductal stenosis	0	0.28	Aqueductal stenosis	0	0.01
3	Aqueductal stenosis	0	0.29	Aqueductal stenosis	0	0.04
4	Aqueductal stenosis	0	0.50	Aqueductal stenosis	0	0.61
5	Aqueductal stenosis	0	0.78	Aqueductal stenosis	0	0.35
6	Aqueductal stenosis	0	1.45	Aqueductal stenosis	0	1.16
7	Aqueductal stenosis	0	4.03	Aqueductal stenosis	0	10.32
8	Aqueductal stenosis	0	4.58	Aqueductal stenosis	0	8.15
9	Aqueductal stenosis	3	1.35	Aqueductal stenosis	2	6.72
10	Aqueductal stenosis	8	12.13	Aqueductal stenosis	4	7.73
11	Meningitis	0	0.36	Meningitis	0	0.57
12	Meningitis	0	0.50	Meningitis	0	0.05
13	Meningomyelocele	2	16.23	Meningomyelocele	2	8.44
14	Meningomyelocele	3	6.04	Meningomyelocele	3	5.68
15	Tectal cavernous malformation	4	15.89	Tumor: cerebellar	4	16.34
16	Tumor: brainstem	0	15.02	Tumor	0	6.13
17	Tumor: cerebellar	0	2.16	Tumor: cerebellar	0	4.38
18	Tumor: hypothalamic	0	0.40	Tumor: thalamic	0	0.42
19	Tumor: midbrain	0	6.92	Tumor: midbrain	0	3.14
20	Tumor: midbrain	0	9.58	Tumor: midbrain	0	14.81
21	Tumor: pineal	0	0.93	Tumor: pineal	0	0.01
22	Tumor: pineal	0	10.40	Tumor: pineal	0	10.37
23	Tumor: pineal	0	15.13	Tumor: pineal	0	12.88
24	Tumor: pineal	0	17.20	Tumor: pineal	0	11.90
25	Tumor: tectal	0	5.57	Tumor: tectal	0	4.31
26	Tumor: tectal	0	11.54	Tumor: midbrain	0	11.21
27	Tumor: tectal	5	14.87	Tumor: cerebellar	6	12.97
28	Tumor: tectal	9	0.61	Meningomyelocele	7	0.72

[a] Age in years at time the index procedure was performed.

for the matched follow-up periods (median, 35 mo). As previously noted, costs that occurred after the initial hospitalization were discounted at a rate of 5% per year. The cost for the initial admission (considered from the point of the index surgical procedure onward) was typically higher in the ETV group ($6603 ± $4577 to $10,999 ± $7216) than in the shunt

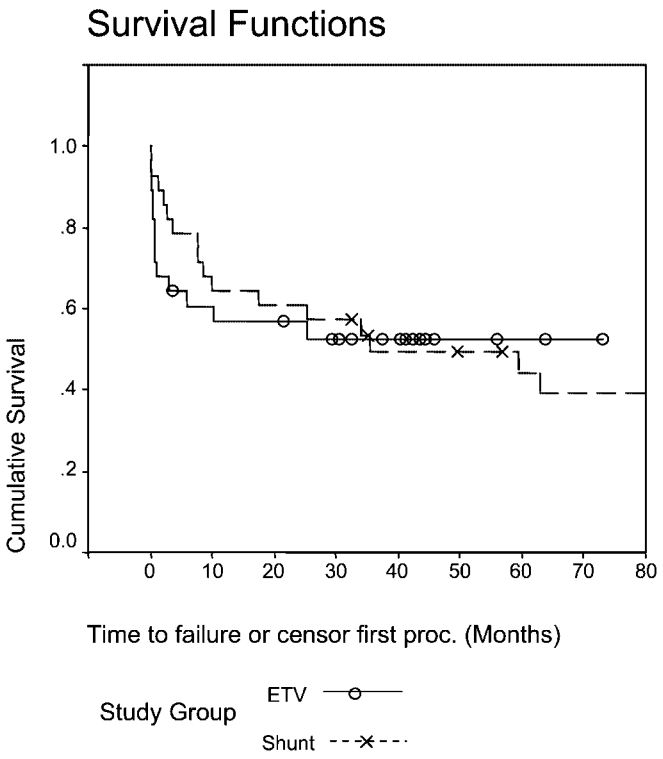

FIGURE 1. *Graph of survival curve for index procedure. Time to first failure for ETV and shunt groups. Note that the curves cross at about 34 months.*

TABLE 2. Resource use[a]

	Endoscopic third ventriculostomy	Shunt	*P* value
Initial hospitalization			
Length of stay	4.82 ± 6.06 d	3.79 ± 2.4 d	NS
Operating room time	2.20 h ± 48 min	1:35 h ± 22 min	NS
Reoperation	4	1	
Subsequent admissions			
Readmission	16	22	
Length of stay			
Cohort total	54 d	91 d	
Mean± SD	3.38 ± 2.28 d	4.14 ± 3.93 d[b]	NS
Reoperations	18	26	
ICU days	1 d	7 d	
Shunt infection	0	2	
Nonhydrocephalus death	4	1	
Hydrocephalus-related death	1	0	

[a] NS, not significant; SD, standard deviation; ICU, intensive care unit.
[b] Shunt group mean length of stay ignoring two admissions for infection, was 3.25± 2.31 days.

group ($5128 ± $2807 to $9023 ± $4849). Subsequent admission costs were similar in both groups, with a low estimate of $5031 ± $3195 and a high estimate of $8430 ± $4646. Outpatient care accounted for approximately 10% of the total cohort costs in both groups.

Including all resources used, patients in the ETV group had lower mean costs ($10,570 ± $7628 to $17,464 ± $12,533) than those in the shunt group ($10,922 ± $8722 to $18,459 ± $14,017), but these differences were not statistically significant. *Figure 2*, using the high-cost estimates, demonstrates the time course over which these costs accrued. As expected, the initial expenditure for the ETV group is greater than that for the shunt group, but after 36 months, the cost streams cross and diverge because of the increased delayed expenses for the shunt group relative to the ETV group.

The ETV group enjoyed an additional 86 days free of treatment of hydrocephalus over the shunt group during the matched follow-up period, again not a statistically significant difference. The cost-effectiveness ratios for the two therapies were between $11.00 and $18.00 dollars per patient per day free of treatment of hydrocephalus for the ETV group and between $11.40 and $18.17 per patient per day for the shunt group. On an incremental basis, ETV was nominally dominant, that is, both slightly less expensive and more effective than shunt therapy (cost/effect ratio <0), with neither difference statistically significant (*Tables 4* and *5*).

Sensitivity Analysis

Varying the discount rate from 1 to 10% produced no significant changes in the relationship between the ETV and shunt groups for either costs or effects. Similarly, altering specific costs by as much as 25% did not dramatically affect the relationship of the ratios (data not shown). Similarly, increasing or decreasing the posthospitalization recovery period by 7 days did not significantly alter the results. As illustrated by *Figure 3*, the ETV costs could be grouped by the success or failure of the initial procedure, with the unsuccessful ETV cases following a cost curve similar to that of the shunt patients, as expected. Using average cost data for the successful and unsuccessful ETV groups, we explored the effects of different rates of ETV success on the cost streams. *Figure 4* demonstrates the results with a hypothetical success rate of 75%, demonstrating that the total cumulative costs for this cohort would cross at about 12 months and continue to diverge thereafter.

Complications and Quality-of-Life Assessment

The main limitation of cost-effectiveness analysis is that it cannot measure different outcomes, yet two patients in the ETV group experienced complications, one of which was fatal.

TABLE 3. Assigned item costs in Canadian dollars[a]

	Assigned cost		
	Low	High	Unit of measure
Antibiotics	$17	$39	Per dose
Neurosurgical consultation			Per visit
Emergency room, ward	$40	$105	
Office visit	$36	$90	
Neurosurgical professional fees			Per case
CSF shunt placement/revision	$904	$1550	
Endoscopic third ventriculostomy	$1153	$2250	
CSF shunt tap	$32	$250	
Anesthesia professional fees	$210	$450	Per case
Radiology professional fees	$75	$150	
Operative costs			
Operative time	$470	$900	Per hour
Anesthetic agents/disposables	$43	$150	Per case
Neuroendoscopic use	$450	$600	Per case
Hardware costs			
Shunt valve	$526	$1500	
Distal shunt tubing	$80	$120	
Ventricular catheter	$60	$90	
Ventricular drainage system	$90	$140	
Radiology costs			Per study
Ultrasound	$105	$175	
Head CT scan	$250	$350	
Brain MRI	$385	$400	
Shunt series/plain x-ray	$55	$100	
Nuclear shunt infusion study	$95	$175	
Laboratory costs			Per study
Basic blood count/chemistry	$20	$40	
CSF analysis (including culture)	$50	$80	
Hospital day costs			
Intensive care unit	$1720	$2500	Per day
Ward	$575	$850	Per day
Emergency room	$110	$175	Per visit

[a] Canadian dollar based upon the value at year 2000. CSF, cerebrospinal fluid; CT, computed tomographic; MRI, magnetic resonance imaging.

These outcomes are poorly represented in the above analysis. To investigate this further, we used quality-adjusted life-year (QALY) techniques to provide an alternative view of the data (12). For the matched pair that included the patient who died, we allowed the follow-up to continue to the last known contact with the patient in the shunt group. We assigned a QALY weight to the days in the follow-up period as follows: 1, day free of hydrocephalus treatment; 0.8, day with hemiparesis; 0.2, days hospitalized or in 14-day recovery period; and 0.0, death. These values are arbitrary but similar to those in the literature (25). When the outcome data in QALYs were recalculated, the ETV treatment remained less costly, but it now became less effective than the shunt group (QALYs, 73.9 versus 78.5), yielding an incremental benefit in the shunt group at a cost of $2153 to $6187 per additional QALY for the low and high estimates, respectively.

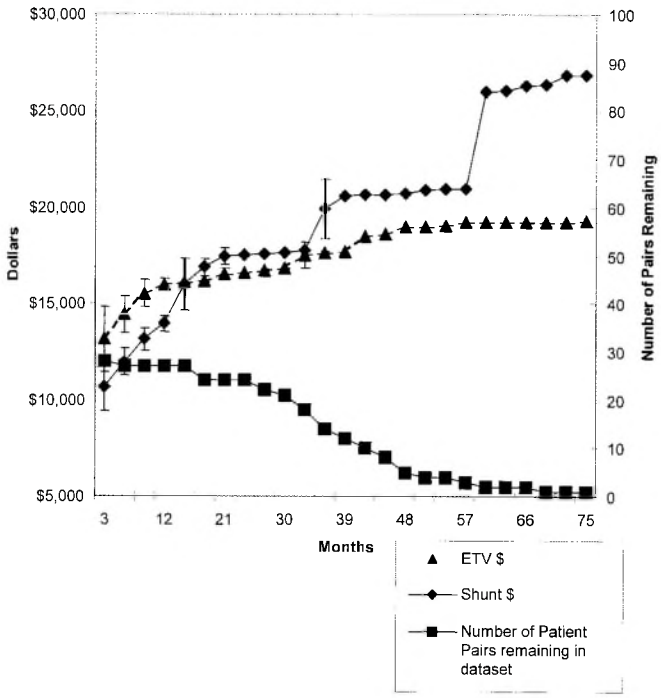

FIGURE 2. *Graph showing cumulative average costs for cohort in Canadian dollars for the year 2000.* Error bars, *standard error.*

DISCUSSION

Is ETV a cost-effective alternative to shunt placement in managing pediatric hydrocephalus? Given the presumed benefits of shunt independence for patients undergoing successful ETV and their reduced reliance on the healthcare system, this might seem to be obviously true. However, up to now, data to support this conclusion have been limited. Barlow and Ching (2) retrospectively identified 23 patients from a group treated with CSF shunts whom imaging studies showed to be potential ETV candidates. They followed the patients' resource consumption over 2 years and calculated that if these patients had undergone ETV with an 80% success rate, 18 repeat operations and 148 hospital days could have been avoided. However, as they note, this analysis assumed a 0% ETV complication rate and did not consider additional shunt malfunctions among patients who needed shunt placement after failed ETV. Ibanez et al. (14) reported that an 82.7% procedural success rate allowed an estimated savings of 9 admissions, 8 reoperations, and 100 days of hospitalization over a 4-year period in a

TABLE 4. Patient outcome[a]

Pair no.	Follow-up (mo)[b]	Discounted treatment-free months[c]		Time to first failure (mo)[d]	
		ETV	Shunt	ETV	Shunt
1	12.62	11.47	11.47	0.39	3.58
2	29.41	27.22	27.08	10.12	9.99
3	32.57	30.6	30.6	—	—
4	43.67	40.31	40.15	—	—
5	55.87	50.49	50.49	—	—
6	34.92	32.03	32.52	2.99	—
7	25.27	23.96	21.77	25.3	7.76
8	40.26	37.3	37.26	—	—
9	21.2	19.63	20.23	0.13	25.3
10	30.5	28.53	28.69	—	—
11	30.33	26.93	28.55	0.13	—
12	12.06	10.91	11.37	0.62	—
13	21.46	19.92	20.41	—	34.05
14	30.13	28.13	27.1	0.33	0.16
15	45.71	42.08	40.99	—	1.28
16	2.86	2.33	1.64	—	0.26
17	35.06	32.77	32.9	0.03	—
18	37.46	34.92	34.95	—	—
19	73.12	64.11	63.57	—	59.42
20	52.88	48	47.49	—	35.33
21	29.31	27.65	27.49	—	—
22	12.13	10.87	11.56	1.02	—
23	28.66	26.53	27.06	0.82	—
24	44.27	40.76	40.07	—	2.17
25	42.49	39.26	37.23	—	17.58
26	41.24	38.28	36.6	—	2.79
27	38.19	34.29	34.49	6.05	8.41
28	64.64	54.93	57.01	0.69	7.79

[a] ETV, endoscopic third ventriculostomy.
[b] Total number of follow-up months.
[c] Months free of treatment of hydrocephalus after 5% annual discount to account for time preference (see text).
[d] Time to first ETV or shunt failure as defined by need for reoperation; —, shunt or ETV reoperation did not occur in follow-up period.

cohort of 58 patients. However, the comparison population from which the shunt experience was drawn was composed predominantly of adult patients with chronic idiopathic adult-onset hydrocephalus. This probably is poorly reflective of the pediatric shunt experience.

What accounts for the lack of more robust gains seen with ETV in our data set? The patients represented in our ETV cohort are typical of those reported in other series. The procedural success rate is lower than the 75 to 80% reported by Cinalli et al. (8, 9) and Goumnerova and Frim (13) but comparable to outcome assessments by Brockmeyer et al. (4) and Tuli et al. (27). Similarly, the patients in the shunt group do not seem to have had an unusual experience with regard to shunt failure. The cost estimates for individual items produced total costs for shunt-related admissions that are comparable to those in the literature (3, 11, 18, 22), and the total cost for managing the cohort was also similar to models reported by Cochrane et al. (10). The resource use experience by the cohort reflects the practice patterns of the senior authors in a tertiary care setting within the Canadian Healthcare system. Possibly, other providers with different practice patterns would produce markedly different patterns of resource use, but given the overall similarity of resource consumption between the ETV and shunt groups, it is unlikely that practice patterns account for the lack of a noticeable difference between the groups. More likely, the deaths of four patients in the ETV cohort relatively early in the follow-up period from diagnoses other than their hydrocephalus (mostly from brain tumors) limited the potential economic and outcome benefits of the procedure. Finally, our mean 35-month follow-up period clearly represents only a small window of time in the life history of many of these children. If late failures after ETV are much rarer than those for children with CSF shunts, longer follow-up would presumably improve the cost-effectiveness ratios seen.

Two key factors most likely account for the majority of the variability in the cost streams of ETV and shunt treatment: the ETV success rate and the rate of ETV complications. The ETV success rate, in turn, is linked principally to patient selection. Our analysis supports these conclusions. For those with pathogeneses typically associated with obstructive hydrocephalus, the success rate was 58%, versus 25% for patients with meningomyelocele or meningitis. Variations in item costs and discount rate had no noticeable impact on our outcome, whereas changes in the success rate had a more obvious effect, as seen in *Figures 3* and *4*. It has been argued that because the benefits of ETV are so dramatic compared with shunt treatment, then perhaps limiting its use to cases in which there is an anticipated success rate of 70% is too restrictive. In fact, Buxton et al. (7) argued that children less than 1 year old be considered candidates, despite a 23% success rate. Although perhaps a higher percentage of such young patients might in due course undergo subsequent successful repeat ETV, our analysis would suggest that, at least over the first 3 years after the procedure, ETV remains more costly without producing significant benefit over shunt treatment until the success rate is higher than 55%. In addition, broader indications for a procedure may be associated with higher procedural complication rates. For patients whose life expectancy falls below the point at which the benefits can be seen to exceed the costs, serious consideration should be given to the CSF shunt treatment as the primary mode of therapy. Our attempt to incorporate the adverse outcomes in the ETV group shows the impact of a single serious adverse event. Although many of the large series cited above report admirably low complication rates, a number of case reports attest to the potential for serious harm (1, 5, 19, 23).

Late deterioration after apparently successful ETV has been reported by others. Cinalli et al. (8) noted one such failure in

TABLE 5. Cost-effectiveness[a]

	ETV	CSF shunt	*P* value
Average cohort costs			
High estimate			
Mean± SD	$17,464 ± $12,533	$18,459 ± $14,017	0.78
Median	$12,534	$12,843	
Low estimate			
Mean± SD	$10,570 ± $7628	$10,922 ± $8722	0.87
Median	$7874	$7667	
Cohort outcome (effectiveness)[b]			
Discounted days free of hydrocephalus treatment (total for entire cohort)	26,914	26,828	0.92
Cost-effectiveness ratio[c]			
Low-cost estimate	$11.00	$11.40	
High-cost estimate	$18.17	$19.30	

[a] ETV, endoscopic third ventriculostomy; CSF, cerebrospinal fluid; SD, standard deviation. Costs are in Canadian dollars for the year 2000.
[b] Mean difference, 3.07 ± 27.47 days.
[c] Shunt patients were marginally more costly (average $351 to $1024) and had 3.07 fewer days in symptom-free state.

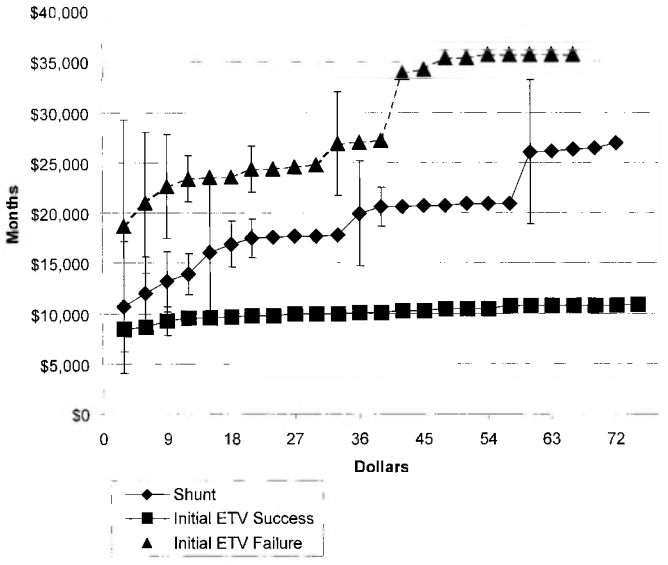

FIGURE 3. *Graph showing average cumulative costs by success or failure of initial third ventriculostomy.* Error bars, *standard error.*

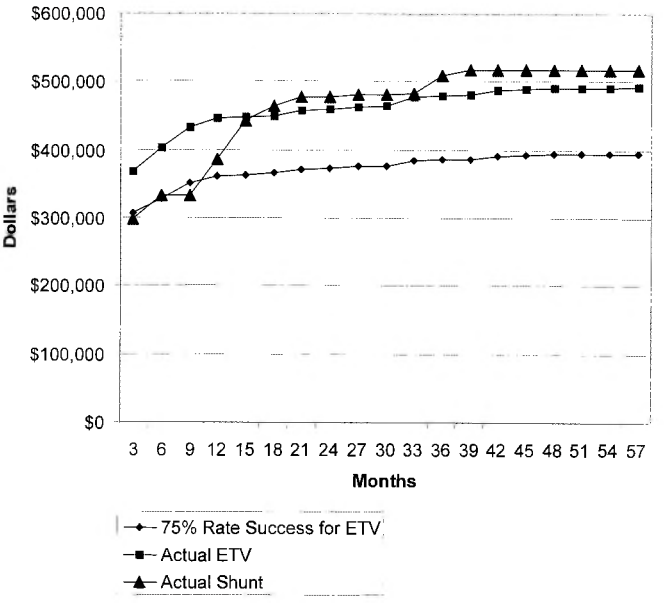

FIGURE 4. *Graph showing modeled total costs for 75% ETV success rate.*

a patient 6 years after performance of the procedure. Our experience of a mortality caused by late failure highlights the need for continued vigilance, even after an apparently successful procedure with confirmatory imaging, in the management of these patients.

CONCLUSIONS

In this cost-effectiveness analysis using a case-control design, we have demonstrated that for this particular cohort, over a median follow-up of 35 months, ETV was not significantly less costly or more effective at producing days free of hydrocephalus than shunt treatment. As expected, the ETV group's resource use was initially higher than that of the shunt group, but subsequent resource use by the shunt group exceeded that of the ETV group such that by 3 years after shunt placement, the cost curves diverged, with ETV clearly less costly. However, ETV in this series was associated with a higher rate of complications, which, when considered in the analyses, tended to limit the beneficial effects of the reduced frequency of hydrocephalus symptoms and reduced medical

resource use. The time course for the accrued costs suggests that a larger cohort, longer follow-up, or higher success rates may be able to demonstrate the cost-effectiveness of this therapy more clearly.

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COMMENTS

This is a heroic attempt to do the nearly impossible, namely perform a cost-effectiveness analysis of third ventriculostomy compared with shunting for children with hydrocephalus. The authors evaluated 28 age- and etiology-matched pairs of patients. The major conclusions were that 1) the endoscopic third ventriculostomy (ETV) procedure ultimately failed in 46% of cases with a median of 35 months of follow-up, and 2) there was no statistically significant difference between the two procedures in terms of costs accrued over the period of the study.

There are some obvious drawbacks to the study, most of which are acknowledged by the authors themselves: the shunts were used earlier in the course of the study, and the ETVs were performed later. The patients with meningitis and meningomyelocele could have been anticipated to fare poorly with ETV and probably should have been excluded. The costs entailed are dubious. Still, the study was probably as well done as practically possible, and the conclusions are probably valid.

The two complications in the ETV group (one death and one hemiparesis) warrant comment. It has been stated by other authors that one of the dangers of ETV is that physicians and parents often assume that the child is shunt-independent after the procedure; herniation and death may occur in the absence of the vigilance that always attends the shunt-dependent child. Shunts are not considered dangerous procedures, but ETV is associated with a number of other complications not seen in this study: aneurysm formation on the basilar artery, basilar perforation, panhypopituitarism, and memory loss. It is to be anticipated that any of these adverse occurrences would prompt a malpractice suit, which might well result in a judgment or settlement in the millions of dollars. This consequence dwarfs any of the analyses presented in this study. In theory, the malpractice component of the relative value unit for each of the procedures takes this into account, but this is very arbitrary for a relatively new procedure such as ETV. One must ask how important any cost analysis is in the setting of a relatively uncommon condition on a global scale. In the final analysis, outcome is the prime issue, and cost is appropriate to consider only if the outcomes are identical. Until the true indications for ETV are defined, this analysis must be considered preliminary, at best.

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This study is a cost-effectiveness analysis of ETV. It compares the financial costs for 28 patients who underwent ETV with those for matched patients who received shunts. It also provides a brief quality-of-life-year analysis. The financial costs were similar in the ETV and shunt patients. ETV had a higher upfront cost, but the shunt patients accrued costs more quickly as time passed. The study suffers from including only a small group of patients. This results in fairly wide confidence intervals in terms of the cost estimates. Single adverse events may have a substantial impact on relative costs. The ETV experience is also relatively small, and it may include an important learning period that influences the length of surgery, complications, and success rate. The authors indicate that a larger study with longer follow-up might clarify these issues. The challenge is for ETV advocates to demonstrate its cost and quality-adjusted life-year effectiveness.

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The care and thoughtfulness with which the authors designed and carried out this study are impressive. Ultimately, cost-benefit analysis is an expression of the long-term efficacy of a surgical procedure (in this case, ETV). The authors have demonstrated to my satisfaction that the cost-effectiveness of ETV is comparable to that of shunting after several years, even when their success rate for the initial ETV is slightly lower than those reported in some other series. After 36, months the trend is toward increased effectiveness of ETV *vis-à-vis* shunting. Given the life expectancy of the patient cohort, one might anticipate that there would ultimately be an unequivocal advantage to ETV in properly selected patients.

The issue of patient selection is also addressed. It is pointed out that, on the basis of the present data, a success rate of at least 55% is necessary to produce a significant benefit of ETV over shunting. In spite of the fact that the ETV success rate in infants is considerably lower than this, if one takes into account that the cost analysis must be amortized over the life of such a patient, it still might be found that ETV is worth trying. The authors have presented a careful and thought-provoking study.

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