Comparison of endoscopic third ventriculostomy alone and combined with choroid plexus cauterization in infants younger than 1 year of age: a prospective study in 550 African children

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Object. The aim of this prospective study was to determine whether, and in which patients, the outcome for bilateral choroid plexus cauterization (CPC) in combination with endoscopic third ventriculostomy (ETV) was superior to ETV alone.

Methods. A total of 710 children underwent ventriculoscopy as candidates for ETV as the primary treatment for hydrocephalus. The ETV was accomplished in 550 children: 266 underwent a combined ETV–CPC procedure and 284 underwent ETV alone. The mean and median ages were 14 and 5 months, respectively, and 443 patients (81%) were younger than 1 year of age. The hydrocephalus was postinfectious (PIH) in 320 patients (58%), nonpostinfectious (NPIH) in 152 (28%), posthemorrhagic in five (1%), and associated with myelomeningocele in 73 (13%). The mean follow up was 19 months for ETV and 9.2 months for ETV–CPC. Overall, the success rate of ETV–CPC (66%) was superior to that of ETV alone (47%) among infants younger than 1 year of age (p < 0.0001). The ETV–CPC combined procedure was superior in patients with a myelomeningocele (76% compared with 35% success, p = 0.0045) and those with NPIH (70% compared with 38% success, p = 0.0025). Although the difference was not significant for PIH (62% compared with 52% success, p = 0.1607), a benefit was not ruled out (power = 0.3). For patients at least 1 year of age, there was no difference between the two procedures (80% success for each, p = 1.0000). The overall surgical mortality rate was 1.3%, and the infection rate was less than 1%.

Conclusions. The ETV–CPC was more successful than ETV alone in infants younger than 1 year of age. In developing countries in which a dependence on shunts is dangerous, ETV–CPC may be the best option for treating hydrocephalus in infants, particularly for those with NPIH and myelomeningocele.

KEY WORDS • hydrocephalus • myelomeningocele • endoscopic third ventriculostomy • choroid plexus cauterization • developing country • pediatric neurosurgery
Clinical Material and Methods

Data Collection and Clinical Evaluation

Data were collected prospectively and entered into a Microsoft Access database (Microsoft Corp., Redmond, WA). Clinical information included history, neurological examination, head circumference, and character of the fontanel. Laboratory data included CSF analysis at the time of the operation. Radiological information included cranial ultrasonography and, when it became available later in the series, a head CT scan. Data recorded at the time of the operation included a description of the intraventricular anatomy and of the ETV procedure (including fenestration of additional membranes below the floor), whether the interpeduncular and prepontine cisterns were open or scarred, whether a septostomy was performed, and the extent of the CPC. The patients were categorized as follows according to the origin of their hydrocephalus: PIH, NPIH, hydrocephalus due to a myelomeningocele, and PHH. Patients with PIH and NPIH were further subcategorized (as previously described) according to age and the status of the aqueduct as noted at the time of ventriculoscopy: Type A (<1 year old with an open aqueduct), Type B (≥1 year old with an open aqueduct), Type C (<1 year old with a closed aqueduct), and Type D (≥1 year old with a closed aqueduct; Table 1). This scheme was not applied to patients with myelomeningocele, however, because of the possibility of unobserved obstruction distal to a patent ostium. Patients with PHH were too few in number for further subdivision.

Patient Selection

Between June 2001 and December 2004, ETVs were performed as the initial treatment in 550 patients presenting with hydrocephalus. The majority of children were from Uganda, but others were from Kenya, Tanzania, Malawi, Somalia, Rwanda, Congo, and Mauritius. The mean and median ages were 14 months and 5 months, respectively; 359 (65%) of 550 were 6 months of age or younger, and 443 (81%) of 550 were younger than 12 months of age. After evaluating the initial results, it was decided to perform bilateral lateral ventricle CPCs in addition to the ETVs to assess the benefit, if any, of the combined procedure among the different patient subtypes.

In the first 230 consecutively treated patients, an ETV alone was performed (with the exception of three patients, who also underwent CPC). In the subsequent 250 patients, a combined ETV–CPC procedure was performed (with the exception of 34 children who underwent ETV alone for various reasons, including a scarred CP). Results of a preliminary analysis in these initial 480 patients resulted in refinement of the protocol for the final 70 patients as follows: 1) an ETV alone in patients at least 1 year of age; 2) an ETV–CPC in all infants with NPIH or PIH Type A (aqueduct open); 3) an ETV–CPC in all infants with myelomeningocele; 4) randomization of infants with PIH or NPIH Type C (aqueduct closed) to either an ETV or ETV–CPC. Overall, a total of 266 patients underwent a combined ETV–CPC, whereas in 284 ETV alone was performed.

Overview of Surgical Technique

The equipment used for the procedure included a flexible endoscope (model 11282 BN), telecam (model SL pal 20212020), xenon nova light source (model 20131520), a Bugby electrocautery wire (all purchased from Karl Storz Co., Tuttingen, Germany), and a monitor (Trinitron PVM-14N5MDE; Sony Corp., Tokyo, Japan). The details of sterilization of the endoscope and camera, operative setup, and the ventriculoscopy procedure in this setting have already been reported.

The floor was fenestrated with a Bugby wire just behind the dorsum sellae by applying brief pulses of electrocautery on the surface followed by blunt penetration through the floor. The wire was used to gradually dilate the opening by gently stretching the tissues. (Fogarty microballoon catheters used by many neurosurgeons to dilate the opening were not available.) The endoscope was passed through the opening in the floor and, when necessary, additional membranes (for example, the Liliequist membrane or arachnoid adhesions resulting from prior inflammation) were penetrated until the endoscope could be passed freely into the interpeduncular and preoptic cisternal spaces. If entry was made anterior to the vertical portion of the Liliequist membrane, obscuring the BA, blunt dissection was accomplished with the tip of the wire to fenestrate the membrane. If the cisterns were found to be scarred from prior meningitis, a similar technique of blunt dissection to open them was also undertaken. The goal of this intracisternal dissection was the direct visualization of a “naked” BA, its branches, and the cranial nerves. The endoscope was withdrawn from the ventriculoscopy, and evidence for flow across the stoma was noted.

As previously described, the lamina terminalis was used as the ETV site if use of the floor was not feasible (usually as a result of scarring from prior ventriculitis), although this is not the preferred site.

Special mention should be made of performing the ETV in patients with a myelomeningocele. The variations in anatomy seen on ventriculoscopy among these patients have already been described. The typically enlarged massa intermedia only rarely precluded access to the floor, which was almost always thickened and revealed no evidence of the BA position below. Interhypothalamic adhesions were common but were usually preserved because the floor was approached around them en passant. The floor was gently and bluntly penetrated posterior to the infundibular recess and anterior to the mammillary bodies, taking advantage, if possible, of a small segment of the floor that was often thinned out. There was commonly a prominent interhypothalamic adhesion crossing the floor in this vicinity. As the floor was gradually penetrated, the dorsum sellae, pituitary, and brainstem came into view. The endoscope was then gently threaded over the wire into the interpeduncular and preoptic cisternal spaces (after fenestration of the Liliequist membrane if needed), which were typically very

### TABLE 1

<table>
<thead>
<tr>
<th>Patient Type</th>
<th>Age (yrs)</th>
<th>Aqueduct</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt;1</td>
<td>open</td>
</tr>
<tr>
<td>B</td>
<td>≥1</td>
<td>open</td>
</tr>
<tr>
<td>C</td>
<td>&lt;1</td>
<td>closed</td>
</tr>
<tr>
<td>D</td>
<td>≥1</td>
<td>closed</td>
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</table>

\[18\]
crowded from anterior displacement of the brainstem and BA complex. In addition, the top of the BA was usually displaced caudally, with its bifurcation forming an acutely angulated Y. As in other cases, blunt dissection of arachnoid adhesions with the tip of the Bugby wire was sometimes required to open up the cistern.

After the ETV, attention was turned to the CPC. Beginning at the foramen of Monro and gradually moving posteriorly, the CP of the lateral ventricle was thoroughly cauterized using the Bugby wire and a low-voltage monopolar coagulating current. In cases of severe ventriculomegaly, a portion of the CP in the anterior roof of the third ventricle was often available for cauterization as well. Care was taken to avoid injury to the thalamostriate and internal cerebral veins or ependymal surfaces. Special attention was paid to coagulating all vessels within the CP completely, including the superior choroidal vein along its entire length. At the level of the atrium, the glomus portion of the CP was thoroughly coagulated. Then, passing the endoscope posterior to the thalamus, its tip was flexed and turned to direct the procedure along the CP of the temporal horn, which was then coagulated in similar fashion beginning from its anterior extreme and advancing the wire posteriorly along its length. Cautery was continued until all visible parts of the CP had been coagulated and shriveled (Fig. 1). For cases in which the septum pellucidum was intact, a septostomy was performed superior to the posterior edge of the foramen of Monro to gain access to the contralateral CP, in which the same procedure was performed in the contralateral ventricle. The bilateral CPC typically added 15 to 30 minutes to the entire procedure.

If the CP was partially scarred from prior inflammation, all residual parts of the CP were coagulated. In several patients with PIH, the CP was sufficiently effaced by scar tissue such that no coagulation was possible. The patients with a myelomeningocele typically had a redundant, robust CP loosely tethered by a thin vascular sheetlike membrane in addition to a carpet of CP adherent to the ependymal surface along the curve of the thalamus.

In cases in which the child presented with infected, turbid, or bloody CSF that precluded initial ventriculoscopy, a reservoir was placed for serial tapping until the fluid was sufficiently clear, as described previously.

Postoperative Follow Up

Patients were generally discharged from the hospital on the 3rd postoperative day, unless their home was too far away. When possible, they were then followed up at 1, 3, and 6 months postoperatively and every 6 months thereafter. Patients lost to follow up were aggressively sought for home visits, often deep in the village, by our social workers, although this was not possible in regions of insecurity. In follow-up examinations, head circumference, characteristics of the fontanel, symptoms, neurological examination, and developmental progress were assessed. Cranial ultrasonography or head CT scanning was also performed at each visit.

Criteria for Success

Success was defined as the avoidance of shunt insertion according to criteria that included a shift in head circumference growth to a normal or less than normal rate as plotted on a standard growth chart, decompression of the anterior fontanel, relief from symptoms of elevated intracranial pressure (such as irritability and vomiting), resolution of eye findings (for example, sunsetting or sixth cranial nerve palsy), and a decrease or arrest in ventriculomegaly as determined on ultrasonography or CT scanning by using the Evans index or frontooccipital horn ratio.

Statistical Analysis

Two-tailed probability values, as calculated using the Fisher exact test, were used to assess the significance of...
outcome differences between treatment groups. A probability value less than 0.05 was considered significant, and statistical power greater than 0.8 was considered necessary to prove the null hypothesis.

Results

A combined ETV–CPC procedure was performed in 266 and ETV alone in 284 patients, for a total of 550 patients. Of the 550 patients, 21 (3.8%) were lost to follow up at less than 1 month postintervention, and these were excluded from any further analysis. Seven patients died within 1 month of the operation (1.3% surgical mortality rate). The mean follow up was 19 months for the ETV group and 9.2 months for the ETV–CPC group.

Origin of Hydrocephalus

The origin of the hydrocephalus in each patient was classified according to previously described parameters. Briefly, the designation of PIH was given if there was 1) no history consistent with hydrocephalus at birth and either 2) a history of febrile illness and/or seizures preceding the onset of clinically obvious hydrocephalus or 3) alternative convincing findings at the time of endoscopy indicative of prior ventriculitis. Patients without an apparent infectious origin of the hydrocephalus were classified as NPIH with the exception of the myelomeningocele group or those in whom the only known antecedent was intraventricular hemorrhage (PHH group). These were considered as distinct groups. The origin was PIH in 320 patients (58%), NPIH in 152 (28%), myelomeningocele in 73 (13%), and PHH in five (1%). This result continues to confirm infection as the principal cause of hydrocephalus in Uganda, as previously reported.

Outcome Based on Treatment

The results according to age are summarized in Table 2. For patients younger than 1 year of age, the outcome success in those undergoing ETV–CPC (66%) was significantly better than that in those undergoing ETV alone (47%, p < 0.0001). This better outcome held true in infants with myelomeningocele (76% compared with 35%, p = 0.0045) and NPIH (70% compared with 38%, p = 0.0025) and approached significance in infants with PIH as well (62% compared with 52%, p = 0.1607, power = 0.3), as presented in Table 3. For patients 1 year of age or older, there was no difference in outcome between the two procedures (80% for each, p = 1.0000).

The results for the various patient types (according to age, origin of hydrocephalus, and whether the aqueduct was patent) are summarized in Table 4. Despite the smaller numbers among these individual groups, a significantly superior outcome for ETV–CPC was apparent among the NPIH Type A patients (63% compared with 20%, p = 0.0037). The difference appeared marked for the PIH Type A group as well, but only approached significance (57% compared with 39%, p = 0.1687). For this group, there was insufficient statistical power (0.3) to rule out a difference, and a larger study group might have revealed a statistically significant result. Thus, for infants with NPIH and PIH, the advantage of the combined ETV–CPC procedure was most pronounced among those with patent aqueducts (that is, the Type A group).

Among the other patient subtypes, the difference in outcome between ETV and ETV–CPC procedures was not significant (Table 4); however, there did appear to be an improved outcome for ETV–CPC in the NPIH Type C group (78% compared with 54%, p = 0.1251) and the statistical power (0.4) was not sufficient to rule this out. The same could be observed in patients with PIH Type D (83% compared with 60%, p = 0.2357, power = 0.3). The number of patients with PIH Type B was insufficient to determine any difference. The patients classified in the PIH Type C and NPIH Type D groups did not appear to benefit from the addition of CPC. No conclusions can be drawn from the small group of patients with PHH, each of whom underwent the combined procedure.

The mean and median times to failure of the initial procedure among all patients were 1.8 and 1.4 months, respectively. Among patients who experienced failures, 95% presented within 6 months of the procedure and 75% within 2 months. Five children (2.5%) with failures, all with PIH, presented late (> 12 months postoperatively). In 61 patients with failure of the initial ETV or ETV–CPC procedure, reopening of an occluded ETV or dissection of membranes below the floor (with or without CPC) was performed, leading to sustained success in 27 who have undergone follow up of more than 1 month. The overall surgical mortality rate (death from any cause within 30 days of the operation) was seven (1.3%) of 550. One patient died of ventriculitis, two of cardiac arrest, one of aspiration, one of pneumonia, and two of undocumented illness at home. There were no intraoperative deaths. In patients undergoing ETV alone, the mortality

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**TABLE 2**

**Differences in outcome based on procedure and age**

<table>
<thead>
<tr>
<th>Procedure &amp; Significance</th>
<th>&lt;1 Yr</th>
<th>≥1 Yr</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETV only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of successes (%)</td>
<td>98 (47)</td>
<td>47 (80)</td>
<td>145 (54)</td>
</tr>
<tr>
<td>total procedures</td>
<td>209</td>
<td>59</td>
<td>268</td>
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<tr>
<td>ETV–CPC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of successes (%)</td>
<td>141 (66)</td>
<td>33 (80)</td>
<td>174 (68)</td>
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<tr>
<td>total procedures</td>
<td>214</td>
<td>41</td>
<td>255</td>
</tr>
<tr>
<td>p value</td>
<td>&lt;0.0001</td>
<td>1.0000</td>
<td>0.0012</td>
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**TABLE 3**

**Differences in outcome based on origin of hydrocephalus in patients younger than 1 year of age**

<table>
<thead>
<tr>
<th>Procedure &amp; Significance</th>
<th>PIH</th>
<th>NPIH</th>
<th>MM</th>
<th>PHH</th>
</tr>
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<tr>
<td>ETV only</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of successes (%)</td>
<td>70 (52)</td>
<td>21 (38)</td>
<td>7 (35)</td>
<td>—</td>
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<tr>
<td>total procedures</td>
<td>134</td>
<td>55</td>
<td>20</td>
<td>—</td>
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<tr>
<td>ETV–CPC</td>
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<td></td>
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</tr>
<tr>
<td>no. of successes (%)</td>
<td>72 (62)</td>
<td>32 (70)</td>
<td>34 (76)</td>
<td>2 (40)</td>
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<tr>
<td>total procedures</td>
<td>117</td>
<td>46</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>p value</td>
<td>0.1607</td>
<td>0.0025</td>
<td>0.0045</td>
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</tbody>
</table>

* MM = myelomeningocele; — = not applicable.
Endoscopic third ventriculostomy alone and combined with CPC

rate was 1.8% (five) of 284 patients and in those undergoing ETV–CPC it was 0.75% (two) of 266 patients. Therefore, mortality rates did not increase with the addition of CPC. There were no cranial neuropathies (except for one patient undergoing ETV who had a transient mild ptosis) or other neurological deficits. No patient suffered injury to the BA, and there were no known endocrinopathies. The infection rate was less than 1%.

Discussion

The history of choroid plexectomy and CPC has been reviewed by others.14,15,19 The terms “choroid plexectomy”19 and “CP coagulation”14 have also been used in reference to the application of electrocautery to destroy CP, but “CPC,” as used by Scarff,15 was settled on for this report. Pople and Ettings14 described the largest clinical series involving endoscopic CPC in their retrospective study of 104 patients who had been examined over a period of 20 years, with sufficient data for evaluation obtained in 92. The mean and median ages at the time of operation were 2 years and 5 months, respectively. Only two of 18 patients with obstructive hydrocephalus were considered to have a successful outcome, whereas 13 (38%) of 34 of those with communicating hydrocephalus and 14 (47%) of 30 of those with hydrocephalus associated with spina bifida were successful in avoiding the need for a shunt. These patients had undergone CPC in the right and left lateral ventricles (many on separate occasions) via an occipital approach by using a rigid endoscope. Other authors have reported the results of CPC for hydranencephaly and chronic infected hydrocephalus in a handful of patients.1,11,19 There have been no prior reports concerning combined ETV and bilateral CPC procedures.

In this series, care was taken to cauterize the entire CP thoroughly in each lateral ventricle. This can be accomplished with the flexible, steerable endoscope, as described in Clinical Material and Methods. In contrast, other authors have described cautery that is limited to the segment of CP from the foramen of Monro to the trigone,13,19 and it has been suggested that CP within the temporal horn is endoscopically inaccessible.21 In the present study, access to the anterior extent of the temporal horn CP was gained in most cases, and the more complete cautery may have contributed to the success. Furthermore, care was taken to coagulate all vessels within the plexus, including the superior choroidal vein. The procedure was not considered complete until all visible parts of the CP and the associated vessels had been thoroughly blanched and shriveled. Although the severity of ventriculomegaly usually encountered in our practice (because of tardy presentation) clearly facilitated endoscopic access to the CP, the temporal horn could be accessed even in patients with moderate ventriculomegaly.

I have previously described the hazards of long-term shunt dependency in sub-Saharan Africa and the advantages as well as the efficacy of hydrocephalus treatment by ETV.16 In that study, ETV alone was successful in more than 80% of children at least 1 year of age regardless of the cause of the hydrocephalus. In addition, in children younger than 1 year of age who had PIH Type C an ETV was successful in 70%. For the remainder of children younger than 1 year of age, however; an ETV was successful in only 31 to 48% of the various patient subtypes (NPIH Type A, PIH Type A, NPIH Type C, and hydrocephalus associated with myelomeningocele). This result was consistent with the less successful outcome in infants reported on by other investigators;2,5,7,16 however, Cinalli and coauthors3 reported outcomes for ETVs in children younger than 6 months of age with aqueductal obstruction that were the same as those in children older than 6 months, and Hellwig and coworkers5 have recently provided an excellent review of the literature.

I postulated that the patients with open aqueducts who were successfully treated by ETV alone may have had an obstruction to CSF outflow (distal to the aqueduct ostium) that was effectively bypassed by the ETV (as previously suggested by Kehler and Gliemroth8), and that those who had failures may have experienced them because of inadequate CSF absorption, whether or not any simultaneous obstructive component existed. Similarly, ETVs may have failed in infants with congenital aqueductal obstruction (NPIH Type C), because sufficient extraventricular CSF pathways and absorptive capacity failed to develop. Conversely, infants with postinfectious (as opposed to congenital) aqueductal obstruction (PIH Type C) may have done well after the ETV because their capacity for CSF absorption could develop prior to the onset of ventriculitis and its resulting obstructive hydrocephalus.

It followed that for those in whom ETV failed because of an imbalance between CSF production and absorption, reducing the rate of CSF production might remedy the problem in some cases. Milhorat and coworkers12 demonstrated in a rhesus monkey model that bilateral lateral ventricular plexectomy reduced the rate of CSF production by approximately 30%. Furthermore, although CPC alone has not gained acceptance as a primary treatment for hydrocephalus, it has proven modestly successful among patients with communicating hydrocephalus.2,11,13–15

It was the premise of this study that for an infant in whom the development of CSF absorption had been inhibited due to congenital obstruction (NPIH Type C), even a temporary reduction in CSF production after bypass of that obstruction (by ETV) might allow the procedure to be immediately successful and allow for the further development of CSF absorption. (This scenario could be the case even if alternative sources for CSF production or any potential regen-

### TABLE 4

<table>
<thead>
<tr>
<th>Procedure &amp; Significance</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td>PIH</td>
<td></td>
<td></td>
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<tr>
<td>ETV only</td>
<td>13 (39)</td>
<td>6 (67)</td>
<td>54 (61)</td>
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<td>total procedures</td>
<td>33</td>
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<td>ETV–CPC</td>
<td>25 (57)</td>
<td>8 (89)</td>
<td>45 (65)</td>
<td>10 (83)</td>
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<tr>
<td>total procedures</td>
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<td>9</td>
<td>69</td>
<td>12</td>
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<td>p value</td>
<td>0.1687</td>
<td>0.5765</td>
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<td>0.2357</td>
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<td>NPIH</td>
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<td>ETV only</td>
<td>5 (20)</td>
<td>4 (67)</td>
<td>14 (54)</td>
<td>17 (100)</td>
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<tr>
<td>total procedures</td>
<td>25</td>
<td>6</td>
<td>26</td>
<td>17</td>
</tr>
<tr>
<td>ETV–CPC</td>
<td>15 (63)</td>
<td>6 (86)</td>
<td>14 (78)</td>
<td>5 (71)</td>
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<tr>
<td>total procedures</td>
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<td>7</td>
<td>18</td>
<td>7</td>
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<tr>
<td>p value</td>
<td>0.0037</td>
<td>0.5594</td>
<td>0.1251</td>
<td>0.0761</td>
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</table>
eral tral bev department of the CP allowed for ultimate restoration of the normal CSF production rate.) It was further postulated that for infants in whom the aqueduct is observed to be open (Type A PIH and NPIH) as well as for infants with myelomeningocele, a reduction in CSF production through CPC would potentially offset any imbalance between production and absorption, whereas the ETV would bypass any obstruction to CSF egress distal to the aqueductal ostium (and thus not observable by ventriculoscopy). This strategy seemed particularly reasonable for the myelomeningocele group, as discussed later.

Whatever the explanation, patients younger than 1 year of age benefited from the combined ETV–CPC procedure. This benefit held true in all infants with congenital hydrocephalus (those with PIH and myelomeningocele) and neared statistical significance in those with PIH as well. Most of the patients with myelomeningocele were observed to have an open but narrow aqueduct on endoscopic inspection; however, the cause of hydrocephalus in patients with myelomeningocele is reported to be multifactorial, stemming from obstruction at some point along the aqueduct, the fourth ventricular outlets, the craniocervical junction, or the arachnoid granulations. The latter concept makes the ETV–fourth ventricular outlets, the craniocervical junction, or the arachnoid granulations. The latter concept makes the ETV–CPC approach especially logical in these patients. (Therefore, for the purposes of this study, the distinction between open and closed aqueduct was not made in the patients with myelomeningocele.) For patients younger than 1 year of age with NPIH and PIH, the superiority of ETV–CPC over ETV alone was most evident among those with open aqueducts (Type A). These patient groups (myelomeningocele and Type A) were precisely those for whom it was hoped that the addition of CPC would be beneficial. The NPIH Type C group (infants with congenital aqueductal obstruction) also appeared to have, as hoped, an improved outcome with the combined procedure. Although the superior outcome for ETV–CPC did not reach significance for either the NPIH Type C or the PIH Type A group, the small numbers of patients in these subgroups failed to provide sufficient statistical power to exclude this from being the case. As anticipated, there appeared to be no added benefit in undergoing ETV–CPC for those with PIH Type C.

It must be pointed out that in our East and Central African patient population, PIH in surviving premature infants is rare, and the data presented here shed little light on the efficacy of ETV–CPC in this special group of patients.

For patient types older than 1 year of age (with the exception of NPIH Type D), the results for ETV–CPC appeared slightly better than for ETV alone, but the differences for these small numbers of patients were not statistically significant. It is conceivable that for some an advantage might have been demonstrated with a larger study group.

Having conducted this trial in a randomized fashion would have added weight to the conclusions; however, when initial observations strongly suggested a benefit for ETV–CPC over ETV alone, it was my conviction that beginning a randomized controlled trial would not be appropriate (because of insufficient equipoise), especially in our unique circumstances. Only late in the series was randomization begun among groups in whom the benefit of the combined procedure was not yet clear.

It could be argued that in the present case better results with ETV–CPC might be due to a learning curve effect (that is, improved technique with the ETV alone), because CPC was added to ETV in the latter half of the patient series. Although this is a consideration that would have been eliminated by a randomized controlled trial, it is an unlikely explanation of the result. An analysis of the success rate in the initial 50 children treated consecutively (with > 1 month follow up) undergoing ETV alone (28 of 50) compared with that in the final 50 children treated prior to the time CPC was added to the treatment protocol (26 of 50) demonstrated no difference (p = 0.8411), despite the experience gained over the intervening period of 1 year, during which time ETV was performed in more than 100 additional children. Furthermore, an overall improvement in the ETV technique with time should not account for the remarkably different result between age groups on adding CPC (< 1 year, p < 0.0001; ≥ 1 year, p = 1.0000).

From this cumulative experience, then, with 550 patients having undergone either ETV or ETV–CPC, it is apparent that shunt placement can be successfully avoided in most of the patients, regardless of age or the origin of hydrocephalus. An ETV was successful in 80% of children older than 1 year of age. The ETV–CPC combination was successful in 73% of infants younger than 1 year of age with congenital forms of hydrocephalus and in 62% of those with hydrocephalus resulting from infection (Table 3). Perhaps the most surprising and encouraging result was the finding that shunt dependency could be avoided from the very beginning in more than 75% of infants with hydrocephalus and myelomeningocele.

These results suggest that ETV–CPC is an effective primary treatment for hydrocephalus in infants, especially in developing countries. Not only might the longer-term risks of shunt dependency be avoided in the majority, but other advantages may pertain as well. In our hospital, both the infection and surgical mortality rates for shunt placement procedures are higher than those reported here for the ETV–CPC procedure. In emerging countries in which poverty, poor infrastructure, and political insecurity render shunt dependence more dangerous, the ETV–CPC procedure may prove to be a good alternative. The stark difference between the respective practice environments should raise caution, however, in interpreting the relevance of these data to developed countries. Although a strong argument can be made for avoiding shunt dependency in developing countries, any long-term advantage of the neuroendoscopic treatment of hydrocephalus in infants and children compared with shunt insertion has yet to be proven, especially with regard to neurocognitive outcome and the incidence of late failure. The importance of longer follow up is understood, and this goal will continue to be pursued.

Conclusions

The primary conclusions that can be drawn from this study are as follows: 1) The ETV–CPC procedure is superior to ETV alone in infants younger than 1 year of age, particularly among those with NPIH and myelomeningocele. 2) Hydrocephalus can be treated successfully in the majority of African infants and children without the use of a shunt, but longer follow up with neurocognitive assessment will be necessary to determine whether this approach is ultimately preferable.
Endoscopic third ventriculostomy alone and combined with CPC

Disclaimer

The author has no financial interest in the materials or processes used in this study.

Acknowledgments

I thank Dr. A. Leland Albright for his review of the manuscript and helpful comments. I especially thank my wife, Cindy, for her patience, commitment, and support.

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Manuscript received March 14, 2005. Accepted in final form September 6, 2005.

The CURE Children’s Hospital of Uganda is funded by CURE International. This work was facilitated by grants from the International Federation for Spina Bifida and Hydrocephalus and the United States Agency for International Development/American Schools and Hospitals abroad.

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