Stereotactic third ventriculostomy in patients with nontumoral adolescent/adult onset aqueductal stenosis and symptomatic hydrocephalus

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Sixteen consecutive patients with obstructive hydrocephalus due to nontumoral aqueductal stenosis of adolescent or adult onset underwent computerized tomography-guided stereotactic third ventriculostomy. Computer-assisted angiographic target-point cross-registration was used in surgical planning to reduce morbidity. The procedure was used as primary treatment in five previously unshunted patients and in 11 patients who had previously received shunts and who presented when their shunts became obstructed (five patients), became infected (five patients), or required multiple revisions (one patient). At the time of third ventriculostomy, shunt hardware was removed in patients with infected shunts and the distal element of the shunt was ligated in all patients with obstructed shunts except one, who later required repeat third ventriculostomy; the distal shunt was ligated at that time. Follow-up data (range 1 to 5 years, mean 3.5 years, after surgery) showed that only one of the 16 patients had undergone a shunting procedure after the third ventriculostomy. The other 15 patients are asymptomatic and shunt-independent. In previously shunt-dependent patients, the peripheral subarachnoid space and cerebrospinal fluid absorption mechanism remained patent in spite of shunts placed earlier. Therefore, in patients with obstructive hydrocephalus due to aqueductal stenosis of adolescent or adult onset, stereotactic third ventriculostomy should be seriously considered as primary surgical management in previously unshunted patients and in shunt-dependent patients with obstructed or infected shunts.

Key Words • hydrocephalus • aqueductal stenosis • shunt • infection • ventriculostomy • third ventricle

The subarachnoid space and cerebrospinal fluid (CSF) absorption mechanisms are usually intact in patients with acquired hydrocephalus. For this reason, methods of "internal shunting" such as third ventriculostomy by open craniotomy or percutaneous techniques, aqueductal reconstruction, and Torkildsen's ventriculocisternostomy have been employed to treat obstructive hydrocephalus. Because of unacceptable rates of operative morbidity and mortality and inconsistent results in the control of hydrocephalus associated with early procedures, neurosurgeons adopted ventriculo-extracranial shunts when the necessary instrumentation became available.

Shunting procedures are now the treatment of choice in the management of all forms of hydrocephalus; certainly, they offer the only reasonable option for most patients with hydrocephalus. Nevertheless, problems associated with shunts are well known to any neurosurgeon. This prompted a re-evaluation of modern techniques for third ventriculostomy in selected cases with acquired obstructive hydrocephalus.

The method for computerized tomography (CT)-based third ventriculostomy with computer-assisted angiographic target-point cross-registration has been described previously. The present paper reports the results obtained with this procedure in the management of patients with obstructive hydrocephalus due to nontumoral aqueductal stenosis of adolescent or adult onset.

Clinical Material and Methods

Clinical Material

Sixteen consecutive patients with aqueductal stenosis of adolescent or adult onset underwent stereotactic
third ventriculostomy between September, 1984, and December, 1989. All presented to a single neurosurgeon (P.J.K.) at the Mayo Clinic. There were 11 males and five females, ranging in age from 10 to 39 years (Table 1). All underwent CT and magnetic resonance (MR) imaging studies which definitively excluded tumor. The initial symptoms of obstructive hydrocephalus in this series occurred in patients between the ages of 10 and 33 years (mean 17 years). Symptoms included headache in 15 patients, learning difficulties in three, defects of vision in six, confusion in two, and gait ataxia in four. The initial diagnosis of aqueductal stenosis was established by CT and/or MR imaging in 11 patients, pneumoencephalography in three, and ventriculography in two.

Stereotactic third ventriculostomy was performed in the following three groups of patients:

Previously Unshunted Patients. Five patients underwent stereotactic third ventriculostomy as an initial treatment for hydrocephalus. These patients, aged 10, 14, 23, 24, and 29 years, had exhibited symptoms for 6 months, 2 years, 7 years, 12 years, and 2 years, respectively. Symptoms consisted of headache in all patients, recent memory disturbance in two, learning disability in two, and gait disturbance in three.

Patients With Shunt Occlusions. Six patients had had shunts inserted as the initial procedure for hydrocephalus at the age of 14, 15, 19, 17, 19, and 33 years, respectively. Previous shunt revisions had been required once in one patient, twice in one patient, six times in one patient, eight times in two patients, and 14 times in one patient. Five of these patients presented with a spontaneously occluded shunt prior to third ventriculostomy. All complained of headache and two exhibited diplopia. Preventriculostomy neurological examination revealed bilateral fourth nerve palsies in one patient; somnolence, disorientation, and Parinaud’s phenomenon in three patients (one with gait disturbance also); and unresponsiveness in the fifth patient. Preventriculostomy CT scans showed moderate ventriculomegaly in all of these patients.

One additional patient (discussed below) requested third ventriculostomy following 14 shunt revisions over a 2½-year period. Her shunt was electively occluded prior to third ventriculostomy.

Patients With Infected Shunts. Five patients treated initially for obstructive hydrocephalus at the age of 14, 15, 19, 24, and 24 years, and who had required one, six, 21, four, and 10 shunt revisions, respectively, underwent third ventriculostomy so that infected shunt hardware could be removed. Shunts in two patients were obstructed as well as infected. All of these patients had headache, two had Parinaud’s phenomenon, and one had bilateral sixth nerve palsies. Three patients presented with ventriculitis; one patient had an infected distal shunt, and one patient (discussed below) had chronic shunt nephritis due to an infected ventriculocaval shunt.

Surgical Approach

The technique for CT-based third ventriculostomy has been described in detail elsewhere.24 Stereotactic frame coordinates are determined for target points in the interpeduncular cistern (at the midline between the basilar artery and dorsum sellae) and in the foramen of Monro, as selected from 1.5-cm thick stereotactic CT slices. Trajectory angles are calculated so that the stereotactic probe traverses the foramen of Monro in the path to the target point in the interpeduncular cistern. Further, target points and trajectories are cross-correlated by computer and displayed on anteroposterior and lateral projections in arterial and venous phases of the carotid and vertebral stereotactic digital angiograms. If no surface vessels are encountered in the trajectory path, third ventriculostomy is performed utilizing a twist drill opening of the skull. If large surface vessels are intersected by the trajectory line, a burr hole is drilled so that surface vessels can be coagulated or retracted and preserved.

Stereotactic third ventriculostomies are performed under general endotracheal anesthesia, the interpeduncular cistern target point is placed in the focal point of the arc-quadrant stereotactic frame* and confirmed radiographically. Calculated collar and arc angles are set on the arc quadrant. A cannula and endoscope† directed by the stereotactic frame are passed into the lateral ventricles, then through the foramen of Monro into the third ventricle to the target point in the interpeduncular cistern (Fig. 1). The endoscope is removed

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* Compass stereotactic system manufactured by Stereotactic Medical Systems, New Hartford, New York.
† Pediatric cystoscope manufactured by Storz Instruments GMBH, Heidelberg, West Germany.
Stereotactic third ventriculostomy

TABLE 1
Case summary of 16 patients with adolescent/adult-onset aqueductal stenosis treated by stereotactic third ventriculostomy*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Onset of Symptoms</th>
<th>First Shunt Revisions</th>
<th>No. Ventriculostomies</th>
<th>Pre-ventriculostomy Symptoms</th>
<th>Neurological Examination</th>
<th>Date of Third Ventriculostomy</th>
<th>Indications</th>
<th>Postop Ventricular Size on CT</th>
<th>Follow-Up Period (yrs)</th>
<th>Outcome</th>
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<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>M</td>
<td>1985</td>
<td>NA</td>
<td>NA</td>
<td>headaches, learning problems</td>
<td>lethargy</td>
<td>1/27/87</td>
<td>increased ICP</td>
<td>decreased</td>
<td>3</td>
<td>asymptomatic</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>M</td>
<td>1983</td>
<td>NA</td>
<td>NA</td>
<td>headaches, seizures</td>
<td>papilledema, iner blind spot</td>
<td>9/28/89</td>
<td>increased ICP</td>
<td>slight decrease</td>
<td>1</td>
<td>asymptomatic</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>M</td>
<td>1983</td>
<td>NA</td>
<td>NA</td>
<td>headaches, diplopia, gait dyspraxia</td>
<td>dyspraxic gait</td>
<td>9/5/85</td>
<td>decreased</td>
<td>5</td>
<td>asymptomatic</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>F</td>
<td>1984</td>
<td>NA</td>
<td>NA</td>
<td>learning difficulties, gait disturbances, headaches</td>
<td>papilledema, headaches</td>
<td>9/13/84</td>
<td>increased ICP</td>
<td>decreased, not normal</td>
<td>4</td>
<td>asymptomatic, ventricles much smaller†</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>M</td>
<td>1973</td>
<td>NA</td>
<td>NA</td>
<td>headaches, decr recent memory, gait ataxia, complex partial seizures</td>
<td>gait ataxia, recent memory impairment, psychomotor retardation</td>
<td>12/11/85</td>
<td>worsening symptoms</td>
<td>decreased not normal</td>
<td>5</td>
<td>significant improvement in gait &amp; memory, no headaches</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>M</td>
<td>1984</td>
<td>4</td>
<td>headaches, papilledema</td>
<td>papilledema, Papinaud's</td>
<td>10/7/85</td>
<td>infected shunt</td>
<td>normal</td>
<td>5</td>
<td>asymptomatic</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>F</td>
<td>1978</td>
<td>6</td>
<td>headaches</td>
<td>Papinaud's, headaches</td>
<td>9/23/87</td>
<td>infected &amp; obstructed shunt</td>
<td>normal</td>
<td>3½</td>
<td>asymptomatic</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>27</td>
<td>M</td>
<td>1986</td>
<td>10</td>
<td>headaches, papilledema</td>
<td>lethargy, confusion</td>
<td>11/30/89</td>
<td>infected shunt, obstructed</td>
<td>decreased</td>
<td>1</td>
<td>improvement, looking for work</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>22</td>
<td>M</td>
<td>1977</td>
<td>1</td>
<td>headaches, papilledema</td>
<td>lethargy, Papinaud's, bilat 6th nerve palsies disoriented, lethargy, headaches</td>
<td>5/10/85</td>
<td>infected shunt, chronic nephritis</td>
<td>normal</td>
<td>5½</td>
<td>asymptomatic</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>28</td>
<td>M</td>
<td>1980</td>
<td>21</td>
<td>headaches, ataxia, blurred vision</td>
<td>shunt tied off</td>
<td>12/14/89</td>
<td>infected shunt, ventricularitis</td>
<td>normal</td>
<td>1</td>
<td>asymptomatic</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>28</td>
<td>M</td>
<td>1978</td>
<td>1</td>
<td>headaches, nausea, vomiting, diplopia</td>
<td>unresponsive</td>
<td>3/2/88</td>
<td>obstructed shunt</td>
<td>normal</td>
<td>2½</td>
<td>normal CT scan, asymptomatic</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>25</td>
<td>M</td>
<td>1977</td>
<td>2</td>
<td>headaches</td>
<td>lethargy, Papinaud's</td>
<td>10/14/86</td>
<td>obstructed shunt</td>
<td>normal</td>
<td>4</td>
<td>asymptomatic, shunt removed</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>24</td>
<td>F</td>
<td>1975</td>
<td>8</td>
<td>blackouts, severe headaches</td>
<td>somnolent, gait disturbance, Papinaud's</td>
<td>8/15/85, 9/23/85</td>
<td>infected shunt, obstructed</td>
<td>normal</td>
<td>5</td>
<td>asymptomatic</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>39</td>
<td>F</td>
<td>1978</td>
<td>6</td>
<td>headaches</td>
<td>headaches, blurred vision, diplopia, bilat 4th nerve palsies somnolent, disoriented, Papinaud's headaches</td>
<td>8/29/85</td>
<td>obstructed shunt</td>
<td>marked reduction</td>
<td>5</td>
<td>asymptomatic</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>27</td>
<td>M</td>
<td>1975</td>
<td>8</td>
<td>headaches, diplopia, confusion</td>
<td>somnolent, disoriented, Papinaud's headaches</td>
<td>3/9/89</td>
<td>obstructed shunt</td>
<td>normal</td>
<td>1½</td>
<td>asymptomatic</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>F</td>
<td>1984</td>
<td>14</td>
<td>headaches, nausea, papilledema</td>
<td>headaches, nausea, papilledema</td>
<td>6/21/88</td>
<td>multiple shunt revisions</td>
<td>normal</td>
<td>2½</td>
<td>asymptomatic</td>
<td></td>
</tr>
</tbody>
</table>

* CT = computerized tomography; ICP = intracranial pressure; Papinaud's = Papinaud's syndrome; bilat = bilateral; decr = decreased; incr = increased; NA = not applicable.
† Age at surgery.
‡ Symptoms recurred in 1988 and a shunt was placed at another institution.
from the guide cannula and replaced with a leukotome. The blade of the leukotome directed anteriorly is opened 6 mm as it is withdrawn from the interpeduncular cistern into the third ventricle. The opening in the inferior aspect of the third ventricle is then inspected through the endoscope before the cannula is withdrawn.

The distal elements of occluded shunts are tied off by separate incisions in the neck in order to prevent intermittent reopening and diversion of CSF flow away from the third ventriculostomy. Shunt elements are removed in patients with clinical evidence of shunt infection or ventriculitis.

Ventriculostomy patency is confirmed by radionuclide scintiventriculography images obtained at 1-hour, 6-hour, 24-hour, and 48-hour intervals following the injection of 500 μCi of indium-labeled diethyleneetriaminepenta-acetic acid and by flow-sequence sagittal MR images as reported previously.

Clinical Follow-Up Data Collection

Patients were evaluated 3 months following the third ventriculostomy by neurological examination and CT in all cases and by MR imaging in patients treated after 1987. All patients were recently contacted by telephone. Inquiries were made regarding symptoms and whether a shunting procedure had been performed at another institution.

Results

Fifteen of the 16 patients in this series with aqueductal stenosis of adolescent or adult onset have not yet required a shunt following stereotactic third ventriculostomy (follow-up period 1 to 5 years, mean 3 1/2 years). However, the third ventriculostomy had to be repeated 5 weeks following the first procedure in one of the patients treated early in the series. One additional patient, an 11-year-old girl asymptomatic for 4 years following third ventriculostomy, had recurrent symptoms and underwent insertion of a shunt at another institution.

All 16 patients experienced resolution of their hydrocephalic symptoms following third ventriculostomy. Headaches and level of awareness improved by the 1st postoperative day. In all patients with papilledema, Parinaud's phenomenon, gait disturbances, and fourth and sixth cranial nerve palsies, the symptoms were noted to have resolved by 3 months following surgery. Radionuclide scintiventriculography showed communication between the third ventricle, interpeduncular cistern, and peripheral subarachnoid convexity by 6 hours following injection in every patient, with flow over the convexities and along the superior longitudinal sinus by 24 to 72 hours.

In this group of patients there were no complications following third ventriculostomy directly attributable to the procedure itself. However, one patient had a mild intraventricular hemorrhage due to removal of an infected ventriculoperitoneal shunt immediately following the third ventriculostomy procedure. He was lethargic for 5 days and then made a full neurological recovery.

Previously Unshunted Patients

In the five patients without prior shunt placement, all preoperative symptoms were relieved following third ventriculostomy. Postventriculostomy CT revealed a 25% reduction of ventricular size in two patients, a 50% reduction in an additional two, and a 75% reduction in the remaining patient. Normalization of ventricular size was not noted in any patient within this group; however, since all of the preoperative symptoms had completely resolved, nothing further was done. Furthermore, radioisotope scintiventriculograms demonstrated CSF flow patterns from the lateral and third ventricles, through the defect in the floor of the third ventricle, into the basilar subarachnoid space, and around the convexities with a normal absorption pattern and rate along the superior longitudinal sinus.

There was one long-term failure in this group. This was a 10-year-old girl with multiple café au lait spots, large head circumference (57.8 cm), and a lifelong history of intellectual slowness in comparison to her nonidentical twin sister. She presented with a 6-month history of headaches and gait disturbance. These symptoms resolved following third ventriculostomy. Postoperative CT scans showed reduction in the size of her lateral and third ventricles; 3 months later, CT showed further marked reduction of ventricular size. She was subsequently lost to follow-up review. Recently, it was learned that she did well for 4 years following third ventriculostomy, when her headaches recurred and she underwent a shunting procedure at another institution. The other four patients remain asymptomatic at 1, 3, 5, and 5 1/2 years following third ventriculostomy.

Patients With Occluded Shunts

Ligation of the distal shunt catheter was performed in all but one of the six patients who presented with an occluded shunt. This step was necessary to prevent intermittent reopening of the shunt and closure of the third ventriculostomy. The only patient in the entire series of 16 patients who required a second procedure for ventriculostomy (5 weeks following the first) was a patient in whom ligation of the shunt had not been performed. At the second procedure endoscopic inspection of the area of the previous ventriculostomy in this patient revealed that glial scarring had occluded the ventriculostomy opening. Following the second procedure, the distal shunt was surgically occluded. This patient remains asymptomatic 4 years following the second stereotactic ventriculostomy procedure. The distal shunt element was also occluded in the patient who underwent elective third ventriculostomy (see below).

Postoperative CT showed normal-sized ventricles in five of these patients and marked reduction of ventricular size in the sixth patient, who had undergone initial shunt placement at 33 years of age. All of these patients...
Stereotactic third ventriculostomy

remain asymptomatic at 1½, 2½, 2½, 4, 5, and 5½ years following third ventriculostomy.

Patients with Infected Shunts

The distal shunt was ligated prior to data acquisition in three patients with functioning infected shunts in order to allow the ventricles and foramina of Monro to enlarge sufficiently for the endoscope to pass. Infected shunt elements were removed following third ventriculostomy.

All five patients in this group noted resolution of their symptoms following ventriculostomy and removal of infected hardware. Postoperative CT revealed marked reduction of ventricular size compared to the pre-ventriculostomy CT scan in one patient (who initially had shunt placement at 24 years of age) and normal ventricles in the other four patients. Follow-up inquiries at 1, 1½, 5, and 5½ years following stereotactic third ventriculostomy revealed that all patients were asymptomatic and doing well.

Illustrative Cases

Case 9: Chronic Shunt Infection

This 14-year-old boy presented in December, 1977, with a 3-week history of severe early-morning frontal headaches and blurring of vision. Papilledema was noted on examination and CT revealed dilated lateral and third ventricles (Fig. 2). The fourth ventricle was normal in size. A ventriculoatrial shunt was placed. His symptoms resolved, and his ventricular system returned to normal size as demonstrated by a CT scan obtained in May, 1985, just prior to removal of his shunt (Fig. 3). A subsequent funduscopic examination was normal. He did well until November, 1984, when his upper and lower wisdom teeth were extracted because of pain and swelling. In January, 1985, he presented with upper lumbar back pain and night sweats. He was found to have microscopic hematuria and an elevated erythrocyte sedimentation rate. Blood and urine cultures were negative. Percutaneous renal biopsy, performed in April, 1985, revealed membranoproliferative glomerulonephritis suggestive of shunt nephritis. Cultures of ventricular fluid withdrawn from the shunt reservoir demonstrated Propionibacterium infection.

The ventriculoatrial shunt was removed on May 10, 1985. Shortly thereafter the patient complained of headache and nausea, and became disoriented. A stereotactic CT scan revealed hydrocephalus (Fig. 4) and
third ventriculostomy was performed without incident. Following this procedure, the patient was alert and oriented, and his headaches resolved. Cultures of the shunt confirmed Propionibacterium. The patient was placed on a course of parenteral penicillin G for 4 weeks. Postoperative scintiventriculography demonstrated excellent flow of the radionuclide tracer out of the third ventricle into the interpeduncular cistern and throughout the subarachnoid space over the convexities with a normal CSF absorption pattern.

The patient has done well and has remained asymptomatic. A CT scan performed on February 21, 1986, showed normal-sized ventricles (Fig. 5). When last contacted on August 20, 1990, the patient was attending graduate school and has remained asymptomatic.

Case 16: Previously Shunted, Multiple Revisions

This 16-year-old girl presented in 1985, 21 years before surgery, with headaches, nausea, and vomiting. A CT scan showed hydrocephalus and a ventriculogram demonstrated aqueductal stenosis. Radioisotope cisternography with the isotope injected by lumbar puncture indicated normal CSF flow and resorption. A right ventriculoperitoneal shunt was placed in March, 1985, and her symptoms resolved. Multiple shunt revisions were required; however, shunt systems functioned for as short a time as 2 weeks. In fact, the patient had undergone 14 shunt revisions before presenting for evaluation to the Mayo Clinic, 6 weeks following her last shunt revision in which a Sophie shunt had been placed. She complained of mild headache, but CT demonstrated normal-sized ventricles. The pressure setting on the Sophie shunt was increased to “high.” Within several hours, the patient complained of headache and nausea. A stereotactic head frame was applied and a CT scan now demonstrated ventricular enlargement. A stereotactic third ventriculostomy was performed on June 21, 1988, and the distal element of the shunt was ligated.

The patient was asymptomatic on the 1st postoperative day and was discharged from the hospital 6 days following stereotactic third ventriculostomy. She returned to Sweden where her neurosurgeon removed the shunt hardware. The patient is now a university student and is still asymptomatic; CT shows normal-sized ventricles.

Discussion

“Internal shunting” procedures have been proposed to exploit the absorptive capacity of the peripheral subarachnoid space in patients with obstructive hydrocephalus. These included open third ventriculostomy by section of the lamina terminalis and/or the floor of the third ventricle, utilizing subfrontal715,29,33,39,40,49 or subtemporal76,67 approaches, percutaneous third ventriculostomy employing free-hand8,16,23,37,38,34,38,48 or stereotactic7,24,40,35,50 techniques, aqueductal reconstruction,1,3,25 and Torkildsen’s ventriculocisternostomy.32,45 All of these procedures have had inconsistent results in the control of obstructive hydrocephalus when all etiologies are considered as a group. However, each of these “internal shunting” operations has been particularly successful in the management of obstructive hydrocephalus in the subgroup of patients with nontumoral aqueductal stenosis of adolescent or adult onset (Table 2). It is therefore not surprising that 15 of the 16 patients in this report did well following stereotactic third ventriculostomy.

Complications

The most frustrating complication is system malfunction requiring operative revisions due to blockage of the ventricular catheter,11,17,20 failure of the valve systems,11 and problems with the site of eventual CSF drainage. These include thrombotic phenomena in ventriculovenous-atrial shunts9,20 and frequent blockage of the abdominal end of the catheter in ventriculoperitoneal shunts,22 but occasional instances have been reported of pseudocysts, bowel perforations, inguinal hernias, bowel obstruction, peritonitis, ascites, and volvulus.3 In addition, infection due to the presence of an implanted foreign body is noted in approximately 8% of contemporary patients.12,37 Mortality rates from infection are as high as 6%.12 Foreign-body reactions can occur even in the absence of infection.13

Fig. 5. Case 9. Computerized tomography scans obtained on February 21, 1986, 8 months following third ventriculostomy, showing normal-sized lateral and third ventricles.
Most shunting systems do not drain at physiological pressures. Overdrainage can cause subdural hematoma, low-pressure syndromes,14,32 and a slit-ventricle syndrome.10,36 These problems seem to be especially frequent in patients with aqueductal stenosis of adolescent or adult onset,19 Antisiphon devices19 may reduce the incidence of overdrainage-related complications. However, instrumentation is subject to malfunction and all of the other general complications related to shunts.

Complications of Third Ventriculostomy

Complications following open third ventriculostomy procedures have been frequent: the mortality rate varied between 5% and 27% (Table 2). Morbidity and mortality associated with free-hand percutaneous third ventriculostomy was much less (2% to 7% and 3% to 7%, respectively).

Theoretically, hypothalamic cranial nerve injury of the fornix and subarachnoid hemorrhage could result from free-hand percutaneous third ventriculostomy. In a series of 46 free-hand percutaneous third ventriculostomies, Sayers and Kosnik26 reported one death following damage to the posterior cerebral artery and hemorrhage, and significant morbidity from permanent hypothalamic damage in another patient. These authors also reported transient diabetes insipidus in three patients, transient midbrain neurological deficits, and transient third and sixth nerve palsies in two additional patients.

Stereotactic third ventriculostomy procedures have been associated with a much lower incidence of complications: no deaths and a morbidity rate of 0% to 5%. Hypothalamic injury is unlikely in obstructive hydrocephalus since the walls of the third ventricle are displaced laterally and the inferior floor of the third ventricle is very thin in the midline and contains no neural elements.5,9,39,40 Stereotactic control ensures that the leukotome is truly in the midline. This reduces the risk of hypothalamic injury and the risk of damage to oculomotor nerves which lie laterally. Furthermore, stereotactic angiographic target-point cross-correlation technique as reported in this paper reduces the risk that instrumentation trajectories damage major vascular structures.

Case Selection

From a review of the literature it is clear that infants are not suitable candidates for third ventriculostomy. However, third ventriculostomy can produce excellent results in older patients with acquired obstructive hydrocephalus. Adolescents, or adults with nontumoral aqueductal stenosis do especially well with “internal shunting” procedures in general, and third ventriculostomy in particular. However, nontumoral aqueductal

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**TABLE 2**

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Target</th>
<th>No. of Cases</th>
<th>% Mortality (% Morbidity)</th>
<th>% Hydrocephalus Arrested</th>
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<tr>
<td>open third ventriculostomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Stokey &amp; Scarff, 1936</td>
<td>FT/LT</td>
<td>4</td>
<td>NA</td>
<td>100%</td>
<td>4</td>
</tr>
<tr>
<td>White &amp; Michelsen, 1942</td>
<td>FT</td>
<td>11</td>
<td>27%</td>
<td>46%</td>
<td>1</td>
</tr>
<tr>
<td>Dandy, 1945</td>
<td>FT</td>
<td>92</td>
<td>12%</td>
<td>39%</td>
<td>29</td>
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<tr>
<td>Guillaume &amp; Mazars, 1950</td>
<td>LT</td>
<td>142</td>
<td>NA</td>
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<td>Scarff, 1951</td>
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<td>54%</td>
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<td>Marelle &amp; Migiavacca, 1959</td>
<td>FT/LT</td>
<td>28</td>
<td>5%</td>
<td>NA</td>
<td>22</td>
</tr>
<tr>
<td>Patterson &amp; Bergland, 1968</td>
<td>LT</td>
<td>29</td>
<td>10%</td>
<td>37%</td>
<td>14</td>
</tr>
<tr>
<td><em>p</em>/techniques</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitter, 1923</td>
<td>FT</td>
<td>1</td>
<td>none</td>
<td>100%</td>
<td>none</td>
</tr>
<tr>
<td>McNickle, 1947</td>
<td>FT</td>
<td>7</td>
<td>none</td>
<td>71%</td>
<td>none</td>
</tr>
<tr>
<td>Guiot, 1973</td>
<td>FT</td>
<td>20</td>
<td>none</td>
<td>75%</td>
<td>14</td>
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<tr>
<td>Ferzari, 1958</td>
<td>FT</td>
<td>15</td>
<td>NA</td>
<td>75%</td>
<td>none</td>
</tr>
<tr>
<td>Pierre-Khan, et al., 1975</td>
<td>FT</td>
<td>44</td>
<td>7% (7%)</td>
<td>50%</td>
<td>17</td>
</tr>
<tr>
<td>Sayers &amp; Kosnik, 1976</td>
<td>LT</td>
<td>46</td>
<td>2% (6%)</td>
<td>47%</td>
<td>none</td>
</tr>
<tr>
<td>Vries, 1978</td>
<td>FT</td>
<td>5</td>
<td>none</td>
<td>40%</td>
<td>none</td>
</tr>
<tr>
<td>Jakse &amp; Loew, 1986</td>
<td>FT</td>
<td>87</td>
<td>2% (3%)</td>
<td>80%</td>
<td>79</td>
</tr>
<tr>
<td>stereotactic techniques</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poblete &amp; Zamboni, 1975</td>
<td>FT</td>
<td>10</td>
<td>none</td>
<td>100%</td>
<td>4</td>
</tr>
<tr>
<td>Zedes des Plantes &amp; Creze, 1978</td>
<td>LT</td>
<td>61</td>
<td>NA</td>
<td>44%</td>
<td>NA</td>
</tr>
<tr>
<td>Hoffman, et al., 1980</td>
<td>FT</td>
<td>24</td>
<td>5%</td>
<td>46%</td>
<td>none</td>
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<tr>
<td>Musolino, et al., 1988</td>
<td>FT</td>
<td>23</td>
<td>none</td>
<td>40%</td>
<td>12</td>
</tr>
<tr>
<td>Kelly, 1991</td>
<td>FT</td>
<td>16</td>
<td>none</td>
<td>94%</td>
<td>16</td>
</tr>
</tbody>
</table>

* FT = inferior aspect (floor) of third ventricle; LT = lamina terminalis; NA = not available/not applicable; AAS = adolescent/adult-onset aqueductal stenosis.
† Includes 10 patients with rupture of lamina terminalis only.
‡ Estimated.
stenosis of adolescent or adult onset must be distinguished from infantile forms of aqueductal stenosis, since in infantile forms the peripheral subarachnoid space may not have developed.8,9 In adult forms, the proposed peripheral subarachnoid space is open and capable of absorbing CSF.8,13

Nontumoral aqueductal stenosis of adolescent or adult onset was first described by Spiller16 in 1902. Many subsequent reports have described the clinical picture and pathology of this entity.8,9,10 Possible etiologies proposed for the subependymal neural glioproliferation in the aqueduct have included developmental anomalies,11 genetic predilection,12 inflammation,13,14 and infection.15,16 However, true cases of adolescent/adult-onset aqueductal stenosis are not common.

Some authors have recommended preventriculostomy radioisotope cisternography to ensure that CSF absorption mechanisms are intact.17 However, the safety of lumbar puncture in a patient symptomatic from obstructive hydrocephalus is debatable. Nonetheless, such a study could be employed in patients with functional infected shunts or in patients considering elective third ventriculostomy in order to escape shunt dependency.

Patency of Third Ventriculostomy

Autopsy studies on patients who have undergone third ventriculostomy reveal short- and long-term patency.4,9,20 Postoperative scintiventriculography proves that peripheral subarachnoid pathways and CSF absorption mechanisms are patent following third ventriculostomy in shunt-dependent patients as well as in previously unshunted patients. Flow-sequence MR imaging has documented continuing patency of stereotactic third ventriculostomy.21

A constant ventricular CSF flow from the third ventricle into the interpeduncular cistern should keep the ventriculostomy open. For this reason it is necessary to occlude the shunt in previously shunted patients undergoing third ventriculostomy so that ventricular fluid does not escape through the shunt and bypass the third ventriculostomy with resultant closure of the ventriculostomy orifice. Even shunts thought to be nonfunctioning should be occluded, since they have been documented to open intermittently.17

Although symptoms of hydrocephalus resolved in every patient in this series, postventriculostomy CT did not always demonstrate normalization of ventricular size. This is consistent with the findings of Musolinio, et al.,20 and Hoffman, et al.18 However, normalization of ventricular size may not be the best endpoint, even in the treatment of hydrocephalus by shunts.14 Ventricular system collapse can cause frequent shunt occlusions and may require third ventriculostomy to free the patient from shunt dependency.16

Conclusions

Third ventriculostomy should be considered in patients with obstructive hydrocephalus due to nontumoral aqueductal stenosis of adolescent or adult onset. The procedure provides good results in previously unshunted patients as well as in those who are shunt-dependent; it is apparent that CSF pathways and absorption mechanisms remain intact in spite of previous shunting. The method described in the present report reduces the operative morbidity rate to acceptable levels and avoids the long-term morbidity associated with shunts.

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