Stereotaxic reconstruction of the aqueduct of Sylvius

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A stereotaxic technique has been developed to cannulate the cerebral aqueduct in patients with hydrocephalus resulting from occlusion of the aqueduct of Sylvius. Precise placement of a 15- to 20-mm long radiopaque prosthesis between the third and fourth ventricles can reestablish the normal cerebrospinal fluid (CSF) pathway. Since 1974, seven patients have undergone aqueductal reconstruction. The surgical goal in this series was to manage the hydrocephalus by creating and maintaining a patent aqueductal channel. The follow-up period ranged from 1.5 to 6.5 years. In four cases, aqueductal reconstruction alone resulted in control of the hydrocephalus, although two patients underwent revisions of their prosthesis. Three patients ultimately required shunts, despite initial symptomatic improvement after reconstruction. In these seven cases (13 stereotaxic procedures), no mortality and no significant operative morbidity were encountered. Although the technique is relatively simple to perform, technical difficulties remain. At present, no clinical or radiographic test adequately discerns the ideal candidate for stereotaxic aqueductal reconstruction. Four patients required stereotaxic revision because of malposition or malfunction of the prosthesis. This approach should be reserved for patients with a short aqueductal occlusion, and normal distal CSF pathways and dynamics. The rationale, technique, problems, and results of stereotaxic reconstruction are presented.

KEY WORDS • cerebral aqueduct • stereotaxic surgery • hydrocephalus

TECHNIQUES for intracranial cerebrospinal fluid (CSF) diversion in patients with aqueductal stenosis have been replaced largely by standard ventriculosystemic shunts, regardless of the etiology of the hydrocephalus. Such an approach undoubtedly has arisen because of the difficulty of differentiating obstructive from communicating forms of hydrocephalus, as well as the simplicity of performing shunt procedures. Nevertheless, shunts are fraught with well known risks and complications.27,34,35 Alternative treatment proposals are still welcomed. When aqueductal occlusion occurs in patients with patent CSF subarachnoid spaces and persistent resorption capability, it is appropriate to reestablish the normal CSF pathway by opening the aqueduct directly. In 1920, Dandy7 reported two cases treated by suboccipital insertion of a catheter through a stenosed aqueduct. By 1922, however, Dandy8,9 had turned to third ventriculostomy as a safer alternative for CSF diversion. Penetration of the lamina terminalis was performed by Stookey and Scarff in 1936.36 Torkildsen's ventriculocisternostomy,41 developed in 1937, remained an attractive approach for many years, offering a certain simplicity and reliability.11,31 More recently, sophisticated techniques for ventriculocisternostomy have been reported by Guiot and others,16,32 using a leukotome and x-ray guidance. Third ventriculostomy has been performed by way of percutaneous,36 microsurgical,2 endoscopic,45 and stereotaxic33 approaches.

In 1949, both Leksell and Norlén reported successful cannulization of the aqueduct,23,29 in which a metal spiral was inserted into the aqueduct to preserve patency. In our department, approximately 20 patients have undergone this procedure, but the long-term results have not been studied systematically. Others have subsequently testified to the feasibility, technical difficulties, and morbidity of opening and maintaining a patent aqueduct after a posterior fossa approach.1,12,14,43 We have successfully opened a membranous aqueductal occlusion by transcutaneously inserting an angiography guide wire through the cis-
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terna magna and fourth ventricle (unpublished data).
Transcutaneous cannulization of the aqueduct in chil-
dren has been proposed, with an angiography catheter
inserted through the anterior fontanel. In 1972, Steiner and Leksell demonstrated that a
tube stereotaxically anchored in the posterior third
ventricle can achieve a patent communication be-
tween the third and fourth ventricles (unpublished
data). This paper describes a modification of this
stereotaxic procedure. We report the operative tech-
nique and results of aqueductal reconstruction in
seven patients with hydrocephalus resulting from
short or membranous occlusion of the aqueduct.

Materials and Technique

Instrumentation

The Leksell stereotaxic system is used in this pro-
cedure. The reconstruction instrument was designed
with the channel containing the aqueductal prosthesis
bent at 10° near the instrument tip (Fig. 1). This angle
allows an approach trajectory of 10° lateral to the
midsagittal plane. Anatomic studies have demon-
strated that this trajectory optimally reaches the mid-
line aqueductal orifice, but avoids injury to central
brain structures and vascular channels. The insertion
instrument itself has two channels which can be used
as an "irrigation circuit" to clear both cell debris
and residual water-soluble contrast material. A radi-
opaque Teflon or polyethylene angiography catheter
has proven to be a most satisfactory prosthesis. Teflon
in particular is inert, light, and sufficiently stiff for the
purpose. Four small "wings" are constructed at one
end of the tube (15 to 20 mm in length) to secure it in
place. The wings are hardened by heating them to
about 500°F to prevent collapse in situ. The insertion
device used in earlier operations has been replaced by
a smaller instrument designed to deliver a narrower
prosthesis (1.5 mm in diameter). When the prosthesis
is ejected into the aqueduct, the wings expand to
prevent slippage of the tube.

Operative Technique

Reconstruction of the Aqueduct. The CX Leksell
stereotaxic frame* permits lateral radiographs to be
taken intraoperatively. The procedure can be per-
formed under local anesthesia in selected cases. With
the patient placed in the sitting position, air is injected
via lumbar puncture to fill the fourth ventricle and
caudal aqueduct. Anatomic detail is often demon-
strated by subtraction technique. By comparing the
operative stereotaxic films with those obtained at
preoperative examinations (same magnification),
stereotaxic coordinates of a target point in the poste-
rior third ventricle are determined. The desired tra-
jectory of the reconstruction instrument is marked on
a lateral operative stereotaxic film. An angle (α) be-
tween the trajectory and the base plane of the stere-
otoxic frame can be measured. The patient is placed
supine, and the semicircular arc of the stereotaxic
instrument is applied according to the desired coor-
dinates. The arc is placed at the same angle to the
frame base as the angle α. Since the prosthesis is
designed to leave the reconstruction instrument at a
10° angle, the probe guide is secured in the arc at 10°
to the midsagittal plane. Thus, the position of the
guide determines the appropriate location of the burr
hole. After trephination, the third ventricle is punc-
tured with a thin needle, and approximately 0.3 ml of
300 mg I/ml metrizamide is injected (Fig. 2). After
clear delineation of the third and fourth ventricles,
minor correction of the coordinates is occasionally
necessary. The puncture needle is then replaced by
the reconstruction instrument (Fig. 3), and the pros-
thesis is extruded through the aqueductal occlusion.
A jet of clear foamy CSF emerging from the air-filled
fourth ventricle indicates penetration of the occlusion.
The instruments are removed, and the correct position
of the Teflon tube is confirmed by lateral and frontal
radiographs (Fig. 4).

Revision of the Aqueductal Prosthesis. If serial fol-
low-up clinical and radiographic assessments reveal
suboptimal placement or function of the prosthesis,
stereotaxic repositioning can be attempted. The ste-
roteaxic frame is reapplied. The target (prosthesis) is
seen on the lateral and frontal radiographs. The third
ventricle is punctured again by way of the
original burr hole, and is outlined with metrizamide.

* CX Leksell stereotaxic frame manufactured by Downs
Surgical Instruments, Decatur, Georgia.
Fig. 2. With the stereotaxic frame attached to the patient's head, lumbar air encephalography is performed to demonstrate the caudal limit of the aqueductal block (horizontal arrow). Stereotaxic puncture of the third ventricle and injection of metrizamide then demonstrates the rostral block. The target point for extrusion of the prosthesis is selected (vertical arrow).

Fig. 3. Left: Lateral radiograph demonstrating the insertion instrument in position just rostral to the occlusion. Right: Frontal radiograph demonstrating the insertion instrument prior to extrusion of the prosthesis.
A thin-cupped biopsy forceps† is directed to one of the wings of the prosthesis (Fig. 5). The image intensifier is used to provide fluoroscopic control. The prosthesis is grasped, and an attempt is made to reposition it in an optimal location.

This procedure was used in four patients. In two cases, an angiography guide wire was first passed through the prosthesis to direct repositioning of the prosthesis (Fig. 6). A flexible fiberoptic endoscope positioned in the third ventricle was used as an adjunct to visualization in one patient.

Patient Selection

Seven patients (four males and three females, ranging in age from 13 to 57 years) were selected for stereotaxic reconstruction. All patients had the onset (or recurrence) of symptoms referable to occlusion of the aqueduct. Two patients had undergone previous CSF diversion procedures, which had malfunctioned. In all cases, preoperative encephalography revealed that a short segment of aqueduct was occluded. Patency of the subarachnoid space and absorption of CSF were studied by lumbar infusion tests and/or isotope cisternography in five patients. Ventricular pressure recording was performed preoperatively in only one case.

Postoperative Course

All of the patients were reevaluated clinically and radiographically after surgery. The follow-up period ranged from 1½ to 6½ years. Evidence of persistent clinical symptomatology or lack of reduction in ventricular size, as assessed by computerized tomography (CT), prompted readmission for follow-up contrast encephalography. Prosthesis malfunction or malposition was revealed in four patients, who then underwent attempted revision. In two cases the revision attempt failed, and in one the patient failed to improve despite radiographic evidence of a patent cerebral aqueduct. In these three patients, shunts were placed.

† Biopsy forceps made by F. L. Fischer, Freiburg, West Germany.

Fig. 4. Lateral (left) and frontal (right) radiographs indicating the optimal prosthesis position after completion of the procedure.

Fig. 5. Lateral radiograph during stereotaxic revision demonstrating microforceps grasping one of the “wings” of the prosthesis prior to repositioning the tube.
Case Reports

In order to elucidate some of the technical problems encountered and the difficulties in preoperative and postoperative evaluations, the cases are summarized briefly below and in Table 1.

Case 1

This 13-year-old boy was admitted for evaluation of bilateral intention tremor, headache, and recent onset of nausea and vomiting. Air encephalography showed massive hydrocephalus due to occlusion of a short section of the aqueduct. The subarachnoid space was wide. Immediately after stereotaxic reconstruction, the tremor diminished and the headache and nausea subsided. Two months later, skull radiographs disclosed that the prosthesis had moved 6 mm posteriorly. Nevertheless, serial CT scans showed a slight reduction of the hydrocephalus. At examination 6½ years postoperatively, the patient remained asymptomatic. He was fully employed and neurologically normal. A recent CT scan revealed residual ventricular enlargement.

Comment

The apparent posterior movement of the tube probably resulted from relief of the preoperative axial pressure cone and shift of the brain stem, rather than actual movement of the prosthesis. Although the ventricles have remained dilated, the clinical symptoms have not recurred.

Case 2

For 10 years, this 39-year-old woman suffered from episodic diplopia, irregular menstruation, and depression. At ophthalmological examination, a bitemporal hemianopsia was detected. Skull x-ray films disclosed an enlarged sella turcica. Further radiographic studies demonstrated a valve-like occlusion of the rostral aqueduct and hydrocephalus. Although air could pass cephalad from the fourth to the third ventricle, contrast material failed to pass from the third to the fourth ventricle. After reconstruction of the aqueduct, her menstrual cycle returned to normal and her visual field defect resolved. Serial CT scans disclosed gradual reduction of ventricular size. At examination 5½ years postoperatively, the patient remains completely asymptomatic.

Comment

Membranous occlusion of the aqueduct is an excellent indication for aqueductal reconstruction. Clinical cure and radiographic normalization followed reconstruction in this case.

Case 3

This 20-year-old man was admitted with complaints of poor memory, personality changes, headache, and vertigo. Three years previously, he had been treated for severe infectious parotitis. He further related a history of a skull fracture and a brain contusion sustained in a fist fight. Encephalography showed a caudal diaphanous membrane which occluded a tortuous aqueduct. After reconstruction of the aqueduct, a transient Parinaud's syndrome was noted for 2 weeks. Although serial CT scans confirmed reduction of the ventricular size, intermittent headaches recurred 6 months postoperatively, and he complained of double vision. Ventriculography performed 4 years after reconstruction showed minimal flow of contrast material from the third to the fourth ventricle. The prosthesis was thought to be in a suboptimal position (Fig. 7).

Revision of the prosthesis was attempted using the endoscopic technique. However, the prosthesis could not be grasped by the forceps. A second attempt to reposition the prosthesis using image intensification also failed. After this last procedure, the patient developed total occlusion of the rostral aqueduct. Placement of a ventriculoperitoneal shunt resulted in complete resolution of his symptoms.

Comment

The distal nature of this patient's aqueductal occlusion posed significant technical problems in positioning the prosthesis. An initial injury to the quadrigeminal plate produced a transient Parinaud's syndrome. The last attempt to revise the prosthesis resulted in periaqueductal edema. Complete closure of the aqueduct rostral to the prosthesis...
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<table>
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<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Preoperative Encephalography</th>
<th>Last Postop Encephalography</th>
<th>No. of Revisions</th>
<th>Subsequent Shunting</th>
<th>Clinical Result</th>
<th>Follow-Up Period (yrs)</th>
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<td>2</td>
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<td>asymptomatic, full employment; persistent ventriculomegaly</td>
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then necessitated a shunt. The relationship of both the infectious parotitis and the head injury to the aqueductal occlusion is intriguing.

**Case 4**

This 55-year-old man had been evaluated 10 years after sustaining a severe head injury and traumatic subarachnoid hemorrhage (SAH). Eight years previously he first developed major motor seizures, followed by progressive dementia. Pronounced ventricular dilatation and a membranous aqueductal occlusion were found on diagnostic studies. Normal CSF dynamics and resorption were indicated by a lumbar infusion test. At surgery, ventriculography
revealed two distinct membranes that occluded the aqueduct. Postoperative contrast and radioisotope ventriculography showed a patent aqueduct, but the ventricular system remained dilated (Fig. 8). Eventually his dementia progressed, and lumbar cisternography showed a probable convexity block. Despite insertion of a functional ventriculoatrial (VA) shunt, he remains unimproved.

Comment
Extensive preoperative testing disclosed a membranous aqueductal occlusion but no evidence of communicating hydrocephalus. Although a patent aqueductal channel was created, the patient failed to improve. The clinical picture may be explained best by a hereditodegenerative disorder, in association with aqueductal occlusion, rather than posttraumatic hydrocephalus.

Case 5
This 57-year-old man was admitted with headaches and dementia. An aqueductal occlusion diagnosed 3 years previously had been treated by a VA shunt. Two years previously, however, this shunt was removed because of infection. A CT scan disclosed symmetrically dilated lateral ventricles with a normally appearing fourth ventricle. A narrower insertion instrument was used than in previous patients. Unfortunately, the prosthesis became dislodged into the fourth ventricle. Nonetheless, the patient's headaches temporarily improved, and his dementia has been less pronounced since surgery. Ventriculography demonstrated a patent aqueduct and a slight reduction in ventricular size. Lumbar isotope cisternography 2 years after surgery revealed intraventricular penetration of the isotope and delayed circulation at the convexity.

Comment
Although the new smaller tube created an aqueductal passage of adequate size, the "wings" of this polyethylene tube were not designed properly and the prosthesis became dislodged. Although patency of the aqueduct was accomplished, the CSF dynamics were obviously abnormal and indicated a partial "com-
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"communicating" form of hydrocephalus. A shunt may yet be required.

Case 6

This 32-year-old woman had meningitis at 3 months of age. A Torkildsen shunt had been inserted when she was 14 years old. She presented with a 1-year history of headaches and major motor seizures. Symmetrical hydrocephalus with a normal-appearing fourth ventricle was demonstrated by a CT scan. Encephalography disclosed a 6-mm midaqueductal occlusion. Although isotope cisternography revealed a slow convexity uptake, an infusion test was normal. After stereotaxic reconstruction, the patient improved for several months, only to suffer recurrent headaches 1 year after surgery. Ventriculography showed partial obstruction to contrast flow at the rostral end of the prosthesis, which was in a good position (Fig. 9). A revision was attempted, but it proved impossible to grasp the prosthesis with the forceps. When the patient's headaches returned again 3 months after the revision, a VA shunt was installed.

Comment

Development of a small membrane at the prosthesis may have impaired proper function, but an attempt to revise the prosthesis failed. Some component of communicating hydrocephalus was suspected, despite the patient having responded well to a Torkildsen shunt for 18 years. Aqueductal reconstruction failed to control this patient's symptoms, and a systemic shunt was placed.

Case 7

This 25-year-old woman was evaluated for a 9-year history of headaches and a 5-year history of major motor seizures controlled with medication. The general physical and neurological examination was unremarkable. A CT scan disclosed symmetrical hydrocephalus. A lumbar CSF infusion test was normal, but monitoring of the ventricular pressure indicated intermittent periods of intracranial hypertension. Ventriculography demonstrated a 5-mm occlusion of the aqueduct, and stereotaxic reconstruction was attempted. Symptoms of increased intracranial pressure necessitated reoperation the next day when ventriculography demonstrated that the prosthesis had failed to penetrate the occlusion completely. By cannalizing the tube with an angiography guide wire, a proper channel was established. The patient's clinical symptoms resolved. Follow-up CT scans at 3 and 19 months postoperatively demonstrated persistent ventricular dilatation but a good position of the prosthesis (Fig. 10).

Comment

A good clinical result was achieved in this patient, despite evidence of persistent hydrocephalus, and no further therapy has been warranted.

Summary of Results

Seven patients underwent stereotaxic reconstruction of the aqueduct. In all cases, preoperative clinical and radiographic studies indicated that a short segmental aqueductal obstruction was the primary cause of the hydrocephalus. The pre- and postoperative radiographic appearances as well as clinical outcomes are shown in Table 1. Revision of the aqueductal...
prosthesis was performed in four cases (six operations) in an attempt to reposition the prosthesis or reopen a partially blocked prosthesis. Three patients (Cases 1, 2, and 7) are regarded as having good results; they are asymptomatic and have returned to full working capacity. Of these three, two still have dilated ventricles. Three other patients subsequently required shunts and are regarded as treatment failures, although in two cases a patent aqueduct was achieved. Despite successful opening of the aqueduct, one patient (Case 5) has improved only marginally.

No operative mortality was encountered in the 13 aqueductal procedures. The only operative morbidity occurred in Case 3, a patient who developed a transient Parinaud's syndrome. The same patient has residual diplopia unimproved from his preoperative status. This patient's shunt was mandated by edematous occlusion of the rostral aqueduct after revision.

Final prosthesis position was considered satisfactory in four patients (Cases 1, 2, 6, and 7), three of whom had good clinical results. Despite adequate placement, Case 6 ultimately required a shunt for partial communicating hydrocephalus. Complete dislodgement of the prosthesis into the fourth ventricle occurred in Case 5, although the aqueduct remained patent. Case 7 underwent early revision of the prosthesis, when a postoperative x-ray film disclosed caudal movement of the tube.

Discussion

Despite Dandy's admonition in 1922 against direct cannulation of the aqueduct,9 later investigators reported the ability to open the aqueduct via a posterior fossa craniotomy.15,17,14,33,29,42 Such approaches have been associated with a relatively high morbidity and mortality, especially when examined in the light of currently available shunt techniques. For many years, Torkildsen's ventriculostomy was the most frequently used treatment for aqueductal obstruction.31,43 While this operation proved superior to previous procedures, many investigators have disputed its efficacy, noting a high failure rate.30 Nor was Torkildsen's procedure always a benign approach.11 Third ventriculostomy remains an alternative CSF-diversionary procedure16,22 but fails to restore the normal CSF pathway, and patency cannot always be assured. Leksell's development of direct aqueductal reconstruction29 and the successful use of a stereotactic technique by him and Steiner (unpublished data) spurred development of the procedure described herein. Because shunt procedures are still associated with a distressingly high complication rate (28% to 50% of cases in some series), safe alternatives are still needed.

Symptomatology in the present series of patients with aqueductal stenosis of juvenile or adult onset is similar to that described by others.18,44 Primary complaints consisted of headaches or other symptoms referable to intracranial hypertension and ventricular dilatation. Three of seven patients had idiopathic seizure disorders, a feature associated with between 12% and 18% of the cases of adult aqueductal stenosis.15,18,44 The origin of the aqueductal occlusion remains speculative in all cases. Nevertheless, the role of traumatic SAH in two cases is intriguing. Similarly interesting was a history of severe parotitis in one case, as mumps (myxovirus) has been implicated in the etiology of acquired aqueductal stenosis.37,40 One patient had bacterial meningitis in infancy but was treated successfully for 17 years with a Torkildsen shunt. This argues against the possibility that the aqueductal occlusion was secondary to long-standing communicating hydrocephalus. In the present series, the length of aqueductal obstruction varied from 2 mm to 6 mm. Four patients had membranous occlusion of the aqueduct, associated with a typical bulbous dilatation near the caudal occlusion.25,28,43 One patient (Case 2) appeared to have a partial valve-like occlusion, which prevented egress of contrast material from the third to the fourth ventricle but allowed slight passage of air from the fourth to the third.

Because the aqueduct is a midline structure, the insertion instrument was angled 10° to the midsagittal plane. This device allows an approach trajectory also angled at 10° and delivery of the prosthesis at 0°, the midsagittal plane of the aqueduct. A prosthesis of suitable dimensions and nonreactivity is mandatory. Prior experience at this institution suggested that metallic spirals placed within the aqueduct via posterior fossa craniotomy tended to descend into the fourth ventricle.54 The radiopaque catheter was selected as the prosthesis since it is relatively inert and can be heated to form the four expanding wings. Direct penetration of the obstruction without prosthesis placement was thought to be unsatisfactory because of the possibility of scar formation later obliterating the aqueductal passage.9 Even with a prosthesis, local reaction probably resulted in partial blockage of the prosthesis in one patient (Case 6). The diameter of the tube (1.5 mm) was selected because the aqueduct is normally 1.5 to 4 mm in width.45 The length of the tube depended upon the length of the demonstrated obstruction. The normal adult cerebral aqueduct varies from 11 to 20 mm.30

Optimal prosthesis placement, verified by skull roentgenograms and postoperative encephalography, ultimately was obtained in four cases. Four patients underwent stereotactic reoperations to move the prosthesis to a better position. Image intensification using the C-arm fluoroscope was valuable in two cases in repositioning the prosthesis correctly. Ventricular endoscopy was used as an adjunct in one case. While the flexible fiberoptic endoscope could be placed within the third ventricle, we were unable to visualize fully the posterior third ventricle or the prosthesis. Ventricular endoscopy using a narrower and rigid instrument positioned stereotaxically may be more useful.19,39,45
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Most importantly, no mortality or significant morbidity occurred in these 13 aqueductal procedures. Only one patient sustained a transient neurological deficit (Parinaud's syndrome). Follow-up CT scans have not revealed any cerebral injury caused by the passage of the probe. No patient has developed a seizure disorder after surgery. Of the three patients with epilepsy before operation, two have had no exacerbation and one has had a reduction in the preoperative seizure frequency.

Detection of those patients who are suitable candidates for aqueductal reconstruction remains the paramount problem with this technique. It is necessary that such patients have patent subarachnoid spaces and adequate CSF absorptive mechanisms. The clinical picture is not helpful. Probably the patients who ultimately required shunts in this series all had some component of communicating hydrocephalus in addition to aqueductal occlusion. Despite extensive pre- and postoperative clinical testing, conflicting results obscured the role of communicating hydrocephalus. Computerized tomography evidence of ventricular enlargement alone has been insufficient to predict results in those patients shunted for occult or normal-pressure hydrocephalus. Radioisotope cisternography has been used extensively to study CSF clearance capacity, but its unreliability as a basis for shunt therapy has been emphasized recently. Lumbar infusion (Katzman) tests have been reported to be helpful in assessing CSF hydrodynamics. In the present series, CSF infusion tests were performed in four cases and were normal in all. Two patients subsequently required shunts for suspected communicating hydrocephalus. Ventricular pressure monitoring in one patient showed periodic elevations of intracranial pressure. Such recordings have been helpful in further defining the CSF dynamics and perhaps in predicting response to CSF shunts. Nonetheless, at present no single test or constellation of tests can accurately predict those patients who have deficient CSF absorption and who should, accordingly, be treated by shunting.

These seven cases emphasize the difficulty in resolving the question of both the etiology and effect of long-standing ventricular dilatation. The primary problem is often difficult to isolate, since long-term aqueductal occlusion may result in obliteration of the subarachnoid space, thus obviating direct aqueductal surgery. Conversely, long-term communicating hydrocephalus has occasionally been found to produce aqueductal stenosis. The treatment goal in this series of seven patients was a direct restoration of the Sylvian aqueduct in an attempt to control hydrocephalus. This stereotactic technique can be used successfully to recanalize the aqueduct of Sylvius. The procedure is safe, repeatable, and precise. Nonetheless, successful therapy must be predicated upon correct preoperative demonstration of patent CSF pathways distal to the aqueductal occlusion. Future technical investigations will be directed toward construction of an aqueductal prosthesis that can be more reliably secured at the site of the occlusion and that maintains long-term patency. Use of a thin, straight stereotactic endoscope might facilitate the initial prosthesis placement by directly visualizing the site of the occlusion. An extension of the prosthesis itself, up to the burr hole, would allow extracranial revision of the prosthesis, as well as permit testing patency of the prosthesis by injection of contrast material.

Future use of the present surgical technique can be recommended for carefully selected cases of aqueductal occlusion. Better prediction of those patients who will benefit from stereotactic aqueductal reconstruction awaits the development of more sophisticated estimates of the anatomic and functional integrity of the CSF pathways.

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