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Endoscopic adjuncts to intraventricular surgery

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The cerebral ventricles, located deep within the brain substance and filled with clear cerebrospinal fluid (CSF), are ideally suited for endoscopic surgery. Endoscopic neurosurgery was first introduced in the early 1900s as a means of diagnosing and treating hydrocephalus. It was abandoned for many years because of poor instruments and poor results. Recently, there has been a resurgence of interest in neuroendoscopy for the management of ventricular pathology as the result of a variety of technical advances, including improved optics, illumination, and miniaturized instruments. Minimally invasive neurosurgery is a concept that holds great appeal, and with the availability of improved instrumentation and surgical experience, this concept is currently practical in the clinical setting. The indications and limitations for endoscopic neurosurgery are still being defined, however. Endoscopes have been used successfully within the cerebral ventricles to treat ependymal and arachnoid cysts, simplify complex loculated hydrocephalus, and treat obstructive hydrocephalus as well as to biopsy and even resect a variety of intraventricular cysts and tumors. This article reviews the history of endoscopic surgery and focuses on its current uses in the management of intraventricular pathology.

History

The first recorded endoscopic neurosurgical procedure was in 1910 by a urologist in Chicago, who introduced a small cystoscope in the ventricle and cauterized the choroid plexus bilaterally in two infants [1]. Walter Dandy, who is considered the father of neuroendoscopy, began using neuroendoscopy in 1918 for the management of hydrocephalus. The initial instrument was a speculum to visualize the lateral ventricles. By 1922, Dandy [2] reported using a Kelley cystoscope to inspect the lateral ventricle in two patients and to coagulate the choroid plexus in one. He coined the term *ventriculoscope*, an instrument that provided clear visualization of the ventricle, but limitations in the primitive instruments available at that time resulted in little advancement in the following decades. Dandy was also the first to perform third ventriculostomy, but he used an open procedure to fenestrate the floor of the third ventricle. In 1923, Mixter [3] reported the first successful endoscopic third ventriculostomy (ETV). After the development of the first valved shunt for the control of hydrocephalus in 1949 by Nulsen and Spitz [4], there was little development in the science of neuroendoscopy.

In 1970, led by the efforts of the physicist Harold Hopkins at the University of Reading in England, the first major advance was made in neuroendoscopy. Hopkins developed the solid rod lens system, which was the prototype of the rigid endoscopes in use today. This significantly improved the illumination, field of view, and image resolution, leading to the development of smaller endoscopes. Hopkins was also credited with the development of the flexible endoscope. Fukushima et al [5] introduced the "ventriculofiberscope" in 1973, which had a 4-mm outer diameter and a flexible tip that could be navigated "around corners" within the ventricles. The miniaturization of optical technology has made it possible to use endoscopic techniques within the ventricles

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and subarachnoid space through exposures small enough to cause minimal disruption of the brain. The indications for neuroendoscopy in the treatment of various disease processes are currently being defined. Neuroendoscopy can be used as an adjunct to conventional open microsurgical procedures (endoscope-assisted procedure) or has some defined and developing roles as a stand-alone tool (endoscopic neurosurgery).

Anatomy

Understanding the endoscopic anatomy is critical, because the view differs from that of conventional "open" surgical approaches. In an endoscopic exposure, only a small portion of the anatomy can be visualized at any one time. Because of the limited field of view, the surgeon must keep in mind that important neural and vascular structures may be located adjacent to the endoscope but outside the exposed field. The absence of stereoscopic vision results in loss of depth perception. The surgeon must learn to use different cues, such as shadows and image brightness, as well as acquire an understanding of the predicted anatomy so as to estimate depth and navigate the ventricular system. In many cases, particularly for fenestration of cysts and where prior surgery has taken place, the use of neuronavigational systems with endoscopy becomes helpful.

The most common approach to the lateral or third ventricle is through a standard coronal burr hole in the midpupillary line, typically on the right side. Often, to improve the angle of approach, if visualization of the posterior lateral horn or middle to posterior portion of the third ventricle is necessary, a burr hole placed 1 to 3 cm anterior to the coronal suture and approximately 3 cm from midline is used. Before introducing the endoscope into the lateral ventricle, the orientation of the camera is adjusted such that movements of the endoscope are concordant to the direction of movement on the monitor. Entrance into the ventricle can be done freehand using anatomic landmarks (following a perpendicular trajectory from the brain surface) or with the use of stereotaxy (frame or frameless). In cases where the ventricles are small, stereotaxy is important in minimizing the complications of passing a 4- to 6-mm introducer sheath. In most cases, I prefer to use frameless CT-based stereotaxy to confirm the trajectory to the target site.

On entering the ventricle, the first landmark to identify is the foramen of Monro. The foramen can often be found by following the choroid plexus anteriorly to where it turns at the foramen to sit on the roof of the third ventricle. If the choroid plexus is not seen, the endoscope may be pointed far anterior into the frontal horn. The foramina are paired structures, each serving to connect the lateral ventricle to the third ventricle. Each foramen has important neural and vascular relations. The head of the caudate nucleus is situated laterally, and the septum pellucidum is located medially. The choroid plexus of the lateral ventricle projects forward to the foramen of Monro and passes through the foramen before turning posteriorly to lie under the roof of the third ventricle. The septal vein, located anteromedially, merges with the thalamostriate vein, located posterolaterally, at the foramen of Monro. The joined veins then pass through the foramen and bend posteriorly to form the internal cerebral vein, which runs in the tela choroidea of the third ventricle. Within the body of the lateral ventricle, if the surgeon becomes disoriented, following the veins that become larger toward the foramen or the choroid plexus will lead the surgeon to the foramen of Monro, which will help to reorient the anatomy. Often with long-standing hydrocephalus, the septum pellucidum can be widely fenestrated, and the left foramen may be seen before the right foramen despite a right-sided entry. Understanding the venous anatomy in relation to the choroid plexus prevents mistaking the left foramen of Monro for the right. The location of the thalamostriate vein in reference to the choroid plexus predicts the anatomic side (Fig. 1).

The anterior columns of the fornices curve ventrally and downward and make up the superomedial and anterior borders of the foramen of Monro. The fornices are paired C-shaped white bundles of axons that represent the major efferent output of the hippocampus, terminating in the mammillary bodies. Damage to the fornix during manipulation of the endoscope passing through the foramen can result in memory loss; however, this is uncommon in unilateral approaches.

On passing the endoscope through the foramen of Monro, the floor of the third ventricle is visualized. There are several recesses and prominences along the floor that serve as landmarks. The mammillary bodies, which appear as two whitish prominences, serve as key landmarks (Fig. 2). Just anterior to the mammillary bodies is the floor of the third ventricle, the tuber cinereum. In cases of hydrocephalus, the floor can be attenuated and translucent, which helps to

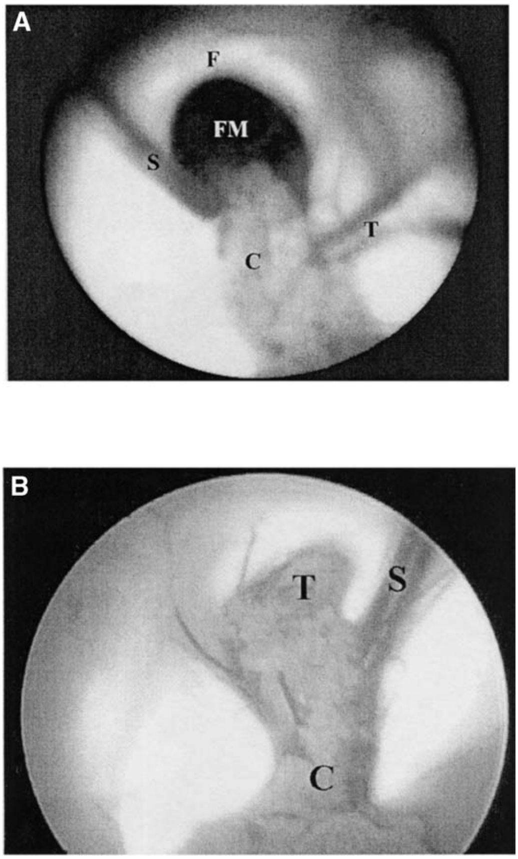

Fig. 1. (*A*) Endoscopic view of the right foramen of Monro. The septal vein is to the right of the choroid plexus. The thalamostriate vein runs lateral or adjacent to the choroid plexus. C, choroid plexus; F, fornix; FM, foramen of Monro; S, septal vein; T, thalamostriate vein. (*B*) View of the left foramen of Monro filled with a colloid cyst. The septal vein is to the left of the choroid plexus. C, choroid plexus; F, foramen of Monro; S, septal vein; T, colloid cyst.

outline the anterior margins of the mammillary body. Often, the tip of the basilar artery can be visualized through the translucent membrane. Staying midline, the anterior portion of the tuber cinereum is a region of increased vascularity into a recess representing the infundibular recess, which descends into the pituitary stalk. Further anteriorly, a horizontal band of white fibers represents the posterior aspect of the optic chiasm. Above this is the optic recess and then the lamina terminalis. It may be difficult to visualize the anterior margins of the third ventricle with a 0° endoscope; however, the anatomy is clearly visible with a 30° scope.

Posterior to the mammillary bodies lies the superior portion of the tegmentum leading into the aqueduct of Sylvius. Further posterior along the floor of the third ventricle is the posterior commissure. These structures may be difficult to visualize with a 0° lens inserted through a coronal approach. Use of a 30° angled lens improves visualization. If the target is along the posterior aspect of the third ventricle, a more anterior approach should be used (2–3 cm anterior to the coronal suture). Alternatively, a flexible endoscope can be used and steered to achieve better visualization of structures that are hard to reach, such as those in the posterior third ventricle, as in aqueductoplasty or tumor biopsy.

Endoscopic equipment

The two most common types of endoscopes used for ventricular access are a rigid rod lens scope and a rigid or flexible fiberoptic endoscope. The highest resolution is through a rigid rod lens endoscope, which provides brilliant images on the monitor. Lens diameters range from 2 to 4 mm (Karl Storz GmbH & Company, Tuttlingen, Germany; Codman, Randolph, MA; Aesculap, Tuttlingen, Germany). Rod lens scopes are introduced with an endoscope sheath or introducer containing working channel(s) as well as irrigation and drainage channels. Illumination is provided by a high-intensity xenon light source transmitted to the endoscope through a fiberoptic cable. A microchip camera (Stryker, San Jose, CA; Karl Storz GmbH & Company) is fitted over the eyepiece of the lens. The camera digitizes the images that are electronically transmitted by cable to an image processor for projection onto a television monitor. Because the camera is mounted to the rod lens system, the device can become quite heavy to hold and maneuver; thus, a fixed camera holder is useful. Hydraulic-based endoscope holders are commercially available (Unitrac, Aesculap; Mitaka, Mitaka Kohki Company, Tokyo, Japan), and some include micromanipulators for fine adjustments in the angle or position of the scope. The superior image quality makes the rod lens system the workhorse for endoscopic surgery.

Fiberoptic endoscopes can either be rigid (Medtronics, Goleta, CA) or flexible. Rigid fiberoptic endoscopes are also designed with working channels. They are introduced into the ventricle through a sheath, which allows for easy entry and removal of the scope during surgery. This also

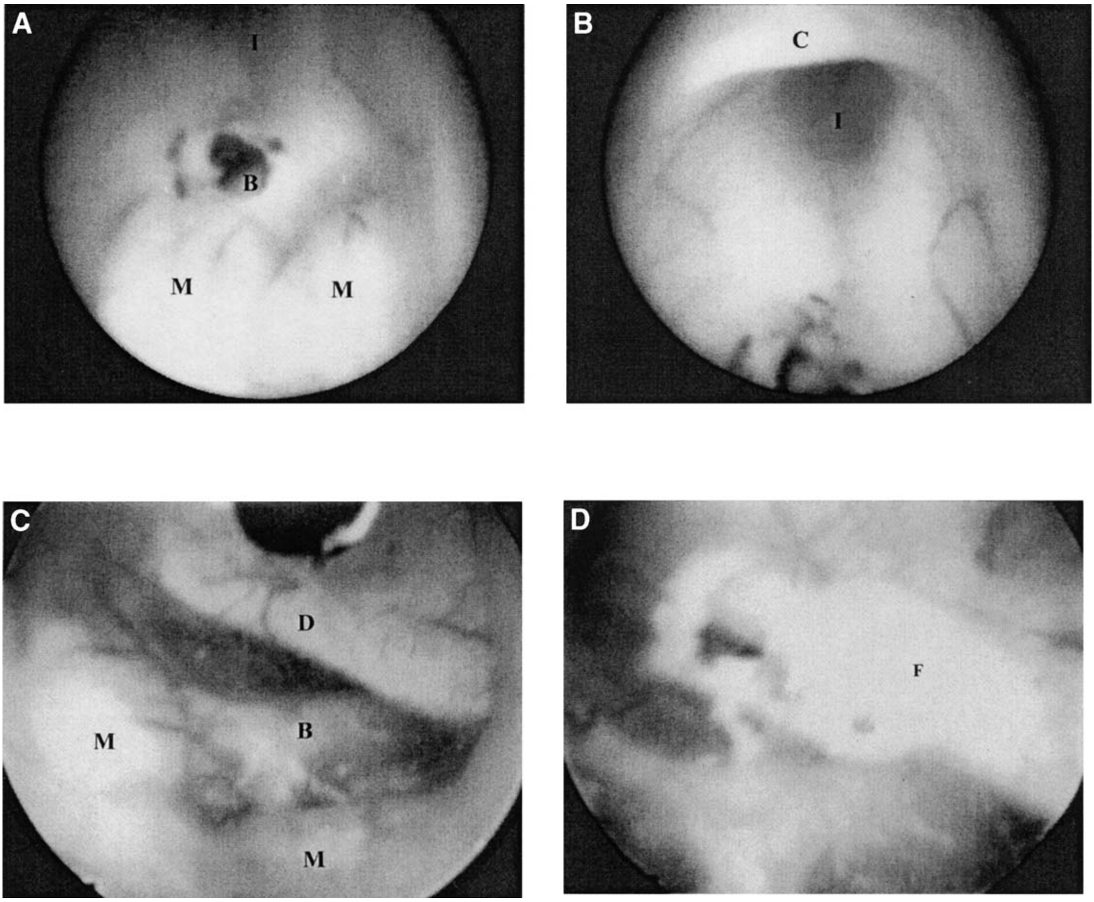

Fig. 2. (*A*) Endoscopic view of the floor of the third ventricle through the right foramen of Monro. The mamillary bodies are prominences that serve as landmarks for the tuber cinereum, which lies anteriorly. The floor may be translucent as in (*C*) or opaque as in (*A*). The ventriculostomy can be seen anterior to the left mammillary body, with the basilar artery lying just underneath and visible through the fenestration. B, basilar artery; M, mamillary bodies. (*B*) Visualizing more anteriorly, the ventriculostomy is now in the inferior view, with the infundibular recess seen anteriorly associated with hypervascularity of the floor and the posterior aspect of the chiasm further anterior. C, chiasm; I, infundibular recess. (*C*) In another case, the floor of the third ventricle is translucent, allowing immediate visualization of basilar artery and dorsum sella. B, basilar artery; D, dorsum sella. (*D*) After fenestration of the floor with bipolar cautery, a Fogarty balloon is passed through the opening to dilate the opening. F, Fogarty balloon.

provides adequate drainage of fluid during continuous irrigation. The main advantage to the rigid fiberoptic endoscope is the light weight and small size of the endoscope, because the images are carried by fiberoptic cable to a camera attached distant to the operative site. In essence, the surgeon only holds the fiberoptic cable traversing through a holder with a working and irrigation channel and a fiberoptic light source. The camera digitizes the images, which are then processed for projection onto a television monitor off of the surgical field. The image quality is dependent on the density of fiberoptic cables and currently does not reach the resolution of rod lens systems.

Irrigation is also important. I prefer to use a pump irrigation system with a foot control. Adjusting the flow rate of irrigation allows debris removal or, more importantly visualization of sites of bleeding. Often, minor bleeding can be controlled with irrigation alone, and the operation can continue. Whenever an irrigation pump is used, it is important to confirm free egress of fluid out of the ventricles either through a drainage channel in the endoscope sheath or around the endoscope if a peel-away sheath is used to cannulate the ventricles. Several endoscopic tools that allow for a greater degree of tissue manipulation are now available. Monopolar and bipolar cautery and a fiberoptic laser introduced into the working channel are available for controlling bleeding or for tissue coagulation. A host of biopsy and grasping forceps, angled dissectors, and microscissors are also available for tissue manipulation. In most cases, the instruments are brought in through the working channel and thus are used coaxial to the line of sight. This is sufficient for most neuroendoscopic procedures; however, in certain cases, such as a complicated colloid cyst, I have found biportal access useful. A second sheath (2 mm) is introduced either anterior or posterior to the endoscope. The endoscopic instruments can be inserted through the second portal under direct visual guidance. This allows for two instruments to work in concert and permits tissue manipulation without the need to move the field of view.

Endoscopic third ventriculostomy

Since Walter Dandy first recognized and described the pathologic importance of aqueduct blockage in the etiology of noncommunicating hydrocephalus in 1922, third ventriculostomy has been performed by means of an open approach, stereotactic approach, and endoscopic direct vision [3,6–8]. The development of a biocompatible shunt at a time when endoscopic instrumentation was limited led to ventriculoperitoneal shunting as the primary treatment of noncommunicating hydrocephalus. The recognition of the long-term complications of shunts and significant improvements in optical technology led to a revival of interest in third ventriculostomy, particularly fueled by the Hopkins rod lens system in 1975 [9]. Currently, ETV has increasingly become accepted as first-line management for patients with obstructive hydrocephalus.

Patient selection is important in determining the benefits of a third ventriculostomy. Success of therapy (defined by clinical improvement and avoidance of a ventriculoperitoneal shunt) has ranged from 52% to 92%. The most favorable outcomes occur in patients with aqueductal stenosis and benign space-occupying lesions of the midbrain or posterior fossa and in patients older than 2 years of age [10,11]. Recently, several reports have documented surprising results in patients with associated abnormalities, such as myelomeningocele, and those who had shunt infections, with success in more than 70% of patients [10–13]. There has been some evidence of efficacy in a subgroup of patients with normal pressure hydrocephalus [14]. ETV would not be effective in patients when CSF absorption is compromised. At times, it may be difficult to determine whether a patient with obstructive hydrocephalus has abnormalities in CSF absorption as well.

The initial workup of patients with progressive hydrocephalus includes structural studies like CT and MRI. The third ventricle must be of adequate size for the endoscope being used so as to avoid damage to the walls of the third ventricle. The floor of the third ventricle should be examined; a downward bulge of the floor of the third ventricle is essential to permit safe performance of this procedure [15–17]. Only then is the ventricular floor translucent, permitting safe perforation. Occasionally, a flat third ventricular floor can be perforated, but this may carry a higher risk of basilar artery or hypothalamic injury. The final question to address is the patency of the subarachnoid spaces. Hoffman [17] and Sayers and Kosnik [18] have previously advocated a preliminary shunt to open up the subarachnoid spaces and improve the success rate of ETV. I do not advocate this, because it seems more logical for the pulsatile CSF flow to be more effective. There are not reliable and routinely applicable clinical tests that can predict whether ETV will be successful. At this time, I as well as other authors think that an initial attempt at management for hydrocephalus from third or fourth ventricle outflow obstruction should be by means of ETV to avoid becoming shunt dependent [10,19,20]. Nevertheless, it is important that adequate information regarding the lower success rates and higher surgical risks compared with shunting be addressed in the preoperative informed consent form.

The operation is performed through a burr hole at Kocher's point. Unless the ventricles are markedly enlarged, I use CT-guided frameless stereotaxy to confirm the trajectory and minimize injury that can be caused by insertion of the endoscope sheath. The rigid fiberoptic endoscope is used for freehand manipulation and visualization. Once the ventricle is entered, the foramen of Monro is identified. The choroid plexus is a useful landmark and can be followed toward the foramen of Monro. The relation between the thalamostriate vein and choroid plexus confirms the left or right side (see anatomy section).

The endoscope is then passed through the foramen of Monro after confirmation of the ventricular side, and the floor of the third ventricle is visualized. The techniques available for perforating the floor vary from blunt perforation using the endoscope itself, a blunt probe such as a Fogarty catheter, or cautery of the floor and atraumatic balloon dilation of the perforation with a Fogarty catheter [13,21]. Special balloons and instruments have also been developed to minimize damage to the hypothalamus and basilar artery. I do not use direct perforation of the floor with the endoscope, because visualization is lost during this maneuver. The translucent membrane anterior to the mammillary bodies is initially perforated by fulguration using bipolar cautery. It is important to make the initial perforation as anterior as possible without approaching the infundibular recess so as to avoid the basilar artery. In cases where the prepontine cistern is compressed or the floor is not translucent, the posterior clinoid can be palpated. The space between the posterior clinoid can be used for penetration, just posterior to the dorsum sella so as to avoid the basilar artery. The Fogarty balloon (2 French) is then inserted into the perforation and expanded such that the diameter of the balloon atraumatically dilates the perforation. I avoid inflating the balloon in the prepontine cistern and withdrawing the catheter through the perforation, because this causes greater trauma to the floor with potential injury to the hypothalamus. Once the perforation is expanded to the diameter of the balloon, the endoscope can be passed through the hole into the prepontine cistern (see Fig. 2). Occasionally, a second membrane beneath the floor may exist (thickened arachnoid or the membrane of Liliequist), which needs to be opened by blunt perforation using the angled probe or Fogarty catheter. Movement of the ragged margins of the perforation with CSF pulse wave is often seen, confirming good flow through the ventriculostomy. If bleeding that obscures the field of view is encountered at any stage and is not cleared completely with irrigation, the procedure should be terminated and an external ventricular drain placed. A further attempt at ventriculostomy can be made 1 or 2 days later if appropriate.

The goal in the management of hydrocephalus is not the achievement of small ventricles but the restoration of normal intracranial pressures and amelioration of the presenting symptoms. In some patients, it may take several days before the subarachnoid pathways for CSF reabsorption become near normal. Even after successful treatment, the perforation may seal closed. A cine MRI examination can sometimes be useful to document flow through the ventriculostomy. Occasionally, monitoring of intracranial pressure is the most definitive way to assess the success of a ventriculostomy. Results of ETV are dependent on the cause of hydrocephalus. In cases of aqueductal stenosis or benign tectal gliomas, the success of ETV ranges from 83% to 100% [10,22–24]. In cases of tumors involving the third ventricle, success decreases to 64% to 83% [10,23]. Patients presenting with obstructive hydrocephalus with enlargement of the third ventricle after subarachnoid hemorrhage or intraventricular hemorrhage (previously shunted) may also respond to ETV, with a 61% to 63% success rate in 54 patients [10,25]. Similarly, patients with obstructive hydrocephalus with a history of infection can be treated with ETV with a successful outcome in 64% of patients [25].

Complications of ETV include arterial or venous bleeding, perforation of the basilar artery, diabetes insipidus, and rare cases of cerebral infarction and death. There have been no deaths as a result of the procedure or arterial injuries at this institution; however, there has been one patient with hemiparesis associated with insertion of the endoscope sheath. There is a learning curve associated with this procedure as with any other, and complication rates vary between 6% and 11% [10,23,26]. Potential complications of ETV are more serious compared with shunting, but fatal risks are rare. Complications of ETV compared with ventriculoperitoneal shunt placement need to be discussed with the patient. Nevertheless, because of the effectiveness of ETV, the improved CSF dynamics, and the elimination of foreign hardware, I think that it should be offered to patients with occlusive hydrocephalus.

Endoscopic colloid cyst resection

Colloid cysts are benign cystic tumors that usually arise from the roof of the third ventricle. In most patients, the lesion presents at the foramen of Monro, causing obstructive hydrocephalus. They can also be observed in the posterior aspect of the third ventricle, or they may involve the septum pellucidum or fornices [27–29]. Patients commonly present with complaints of headache, nausea, emesis, memory loss, gait disturbance, or visual obscuration. Rare cases of sudden death or acute obstructive hydrocephalus have been reported [30]. More recently, asymptomatic cysts are being identified through the increased use of MRI.

Treatment of colloid cysts includes conservative observation in lesions less than 1 cm without hydrocephalus with serial MRI scans, ventricular shunting to manage the hydrocephalus, and removal of the lesion. Incidental colloid cysts less than 1 cm without hydrocephalus can be managed with serial observation, with treatment reserved for those lesions that grow, cause ventriculomegaly, or become symptomatic. Colloid cysts have traditionally been treated by microsurgical resection through either a transcallosal or transcortical approach. Minimally invasive therapies include stereotactic and endoscopic aspiration of the cyst, although these are associated with a high rate of recurrence [31–35]. The use of endoscopic surgical procedures for resection of colloid cysts has been developing over the past 10 years. With the further development of endoscopic instruments, more radical resections are achievable through a minimally invasive approach. This has the advantage of carrying little morbidity with a shorter operative time and hospital stay. Long-term results are not available, however, although the short-term results seem promising [36,37].

The procedure involves positioning the patient supine, with the neck flexed 15° above the horizontal plane. I routinely use neuronavigation to project the angle of approach accurately. Unlike third ventriculostomies, the burr hole should be placed more anteriorly to better visualize the posterior aspect of the foramen of Monro. For single portal access, a burr hole is place 1 cm anterior to the coronal suture and 3 cm lateral to midline. A second portal can be placed 1 cm anterior to the first portal. I have found that the use of two portals aids in manipulation of the tumor tissue to allow more radical resection and improve safety. Often, tissue can be retracted with one instrument and cauterized or incised with the other, without the limitation of working with both instruments in the same trajectory. Operating with instruments in a coaxial fashion limits the degrees of freedom with which the tissue can be manipulated and visualized. The additional portal using a 3-mm sheath is inserted under stereotactic guidance.

The goal of surgery is complete tumor resection, but with safety in mind, a remnant along the roof of the third ventricle or the internal cerebral vein is often left behind and cauterized. The initial visualization is through the 0° scope. The relation of the colloid cyst to the foramen of Monro, choroid plexus, fornix, septum pellucidum, and deep venous system is determined. Often, choroid plexus overlies the cyst wall and needs to be cauterized for better visualization. With large lesions, the cyst wall is cauterized and punctured so as to remove as much of the cyst contents as possible. A silastic catheter can be inserted into the cyst for aspiration of cyst contents. Because of the viscous nature of the colloid material, piecemeal removal of the cyst contents can be performed using cup or alligator forceps. Once the cyst is decompressed, the wall can be grasped and separated from the fornix. The cyst wall can be cauterized to help shrink the overall contents. The lesion can then be delivered into the ipsilateral ventricle for complete extirpation. Care must be taken not to place excessive traction on the cyst wall so as to prevent injury to venous structures from the tumor attachment to the tela choroidea adjacent to the venous angle. If the cyst does not separate easily, the free portions are excised with microscissors and the remaining fragment is cauterized, taking care not to coagulate the thalamostriate or internal cerebral veins. A final inspection of the tumor resection is performed using the 30° angled scope. The septum pellucidum is also fenestrated, and the scope is passed to the contralateral side to visualize the contralateral foramen of Monro for any tumor remnants and for patency of the contralateral foramen. Depending on the degree of blood or tissue debris in the ventricles, an external ventricle drain can be left in place for overnight drainage and evacuation of ventricular contents. Patients are monitored in the intensive care unit overnight.

The lower morbidity and shorter operative time and hospital stay have been documented by several investigators [36–39]. Bauer and Hellwig [40] described the endoscopic treatment of 70 cystic lesions, including colloid cysts, with a morbidity rate of 1.4% and no mortality. The first comparative study of microsurgery and endoscopy was conducted by Lewis et al [41], who found shorter operative, hospitalization, and rehabilitation times and achieved a lower complication rate with the use of endoscopic treatment. Those results were confirmed by Kehler et al [42] and King et al [37]; in these reports, the average operating time for endoscopic procedures was 94 minutes and the average total hospital stay in the endoscopic group was 2.3 days. It is important, however, not to compromise treatment efficacy for "less invasiveness." A review of the recent literature with

Table 1
Outcome from endoscopic colloid cyst resection in the modern era

Author	Year	No. cases	Extent of resection	Follow-up	Recurrence (time)
Abdou and Cohen	1998	13	10 near-complete resection 3 subtotal resection	7 years	None
Decq et al	1998	15	12 aspiration of cyst, coagulation of cyst wall 3 partial removal	15.2 months	1 (18 months)
King et al	1999	12	10 gross total resection 2 subtotal resection	24.5 months	0
Gaab et al	2002	12	1 no resection/observation 8 gross total resection 3 near-complete resection	56 months	0 symptomatic 1 asymptomatic (93 months)
Hellwig et al	2003	20	1 gross total resection 19 subtotal resection (coagulation of cyst wall)	62 months	1 requiring reoperation (72 months)

follow-up (Table 1) shows promising results; however, long-term follow-up is necessary. Although there is a high incidence of recurrence with simple aspiration, with endoscopic surgery, most of if not all the cyst contents can be removed safely and the cyst wall resected. Often, an attachment of the cyst wall to the roof of the third ventricle is coagulated and left behind to avoid injury to the deep venous systems (Fig. 3). In cases of near-complete resections, the significance of a small remnant cyst wall when related to recurrence remains unclear, and only with long-term follow-up will this be understood.

There are several situations in which endoscopic colloid cyst resection may be difficult or impossible. The presence of small ventricles poses a technical difficulty and may carry higher morbidity with difficulties in cannulating the ventricles as well as in manipulating the cyst wall [37]. Second, recurrent colloid cysts become technically challenging because of the loss of anatomic landmarks, cicatrix formation within the ventricles, and greater adherence of the recurrent cyst wall to the adjacent structures. Finally, a small lesion located in the roof of the third ventricle and posterior to the foramen of Monro would be hard to remove with the rigid endoscope and would be associated with an increased risk of injury to the fornix.

Our early experience and the results of other centers suggest that rigid endoscopy is an excellent alternative to the established microsurgical approach. In the hands of well-trained surgeons, with improved endoscopic instruments, this technique can be considered the first method of choice. Long-term follow-up is necessary to determine if endoscopic surgery is a suitable replacement for microsurgical strategies.

Management of pineal region tumors

Surgery has assumed an important role in the management of pineal region tumors. Radiographic features are not diagnostic, and therapy and outcome are dependent on tumor type. Management of hydrocephalus requires urgent attention, because patients can develop acute obstruction and a herniation syndrome. Nearly all patients with pineal region tumors present with symptomatic hydrocephalus. The standard of care has been placement of a ventriculoperitoneal shunt, at which time CSF can be collected. More recently, endoscopic management of obstructive hydrocephalus with a third ventriculostomy, CSF sampling, and biopsy of the tumor has gained popularity. Disadvantages of a permanent ventriculoperitoneal shunt for the initial management of hydrocephalus in these patients include shunt malfunction, infection, and, rarely, peritoneal seeding of tumors. In many cases, if the tumor can be removed, the patient may not need the shunt at all. ETV allows for successful treatment of the obstructive hydrocephalus and collection of CSF for markers and cytology and permits multiple biopsies under direct endoscopic vision as a one-step procedure [43]. I have used this approach in the initial management of all patients with pineal region tumors presenting with hydrocephalus. In patients with a pineal region mass with hydrocephalus, a third ventriculostomy is performed as described previously. CSF is also

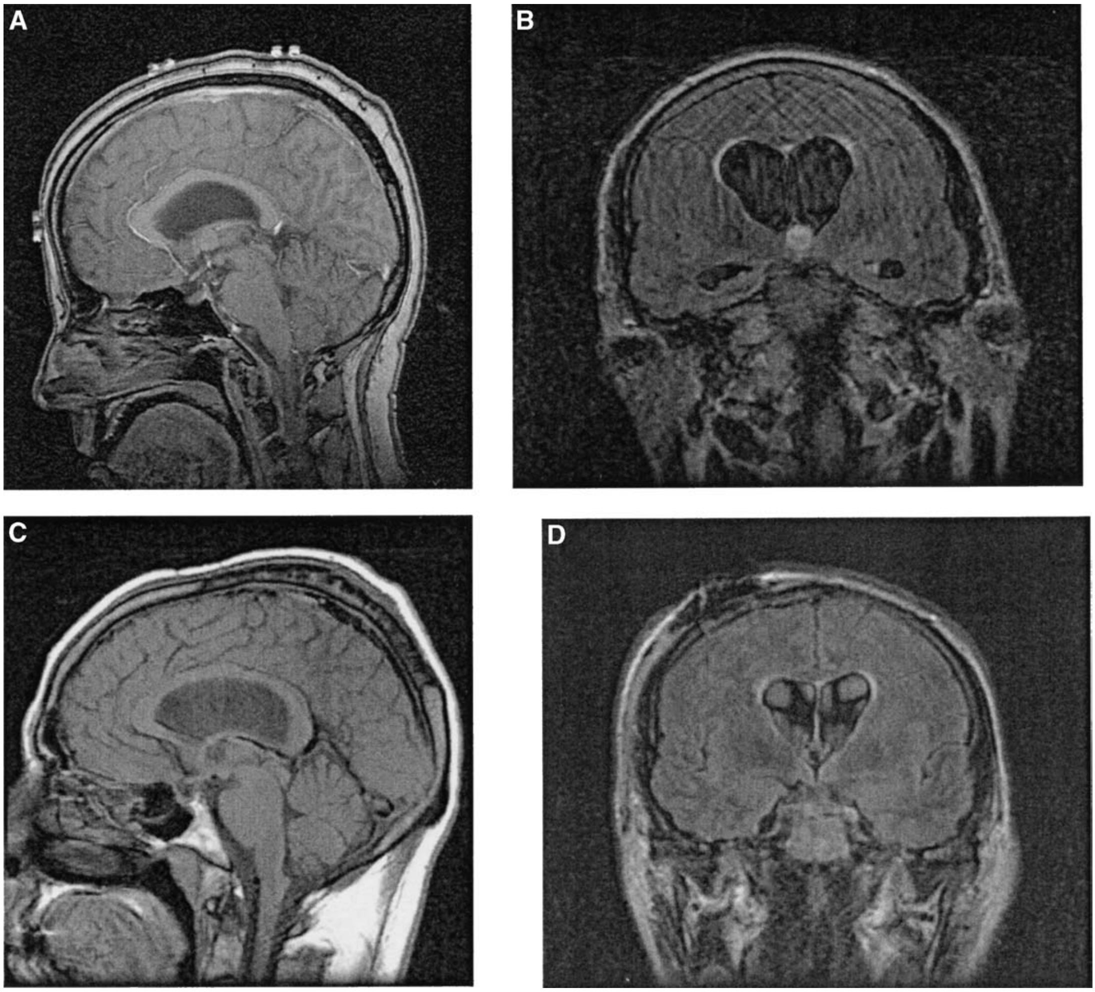

Fig. 3. (*A, B*) Preoperative sagittal precontrast T1-weighted and coronal fluid attenuated inversion recovery (FLAIR) images demonstrating the colloid cyst associated with hydrocephalus. (*C, D*) Postoperative imaging after endoscopic cyst resection. No visible remnant of the cyst is seen, and the ventricles have decreased in size. The patient's imaging studies show no cyst recurrence at 24 months of follow-up.

sampled at this time for tumor markers. If the anatomy is appropriate, a biopsy can be performed under direct endoscopic visualization. To biopsy a lesion in this location, a more anterior burr hole is necessary to reach the posterior third ventricle. This is a particular case where the flexible endoscope could be beneficial. If the biopsy is adequate and demonstrates a germinoma or primary malignant glioma without significant mass effect, the patient is managed with radiation and chemotherapy. For non-germinoma germ cell tumors (NGGCTs), pineal cell tumors, and large glial tumors, the patient can then undergo a more elective craniotomy appropriate for the location and size of the tumor. A concern with endoscopic biopsy is sampling error. Germinomas can contain nests of malignant germ cell tumors that would significantly alter therapy and outcome. Likewise, a glial tumor may contain mixed cell types or focal areas of a higher grade neoplasm, although this is less of a problem, because radiographic appearance can help in choosing the most appropriate region to biopsy.

Summary

Recently, endoscopic intraventricular surgery has been performed successfully in several clinical series. Although the therapeutic results must be compared with conventional surgery, neuroendoscopy seems to be a safe surgical technique when performed by surgeons with appropriate experience and refined endoscopic tools. Rigid or flexible endoscopes equipped with various-sized working channels should be selected depending on the nature of the pathologic findings. The well-proven tenets of microsurgery must not be sacrificed for the sake of more rapid surgical time and noninvasiveness; thus, endoscopic surgery must adhere to the principles of microsurgery. The improved visualization and lower morbidity have established neuroendoscopy in the management of specific disease processes, such as obstructive hydrocephalus. Its further use in the management of intraventricular cysts and tumors is dependent on long-term follow-up and the development of even better instrumentation.

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