Paolo Cappabianca, M.D.
Department of Neurosurgery,
Università degli Studi di
Napoli Federico II,
Naples, Italy

With contributions from

Giuseppe Cinalli, M.D.
Naples, Italy

Michelangelo Gangemi, M.D.
Naples, Italy

Andrea Brunori, M.D.
Rome, Italy

Luigi M. Cavallo, M.D., Ph.D.
Naples, Italy

Enrico de Divitiis, M.D.
Naples, Italy

Philippe Decq, M.D.
Creteil, Paris, France

Alberto Delitala, M.D.
Rome, Italy

Federico Di Rocco, M.D.
Rome, Italy

John Frazee, M.D.
Los Angeles, California

Umberto Godano, M.D.
Cagliari, Italy

André Grotenhuis, M.D.
Nijmegen, The Netherlands

Pierluigi Longatti, M.D.
Treviso, Italy

Carmelo Mascari, M.D.
Bologna, Italy

Tetsuhiro Nishihara, M.D.
Tokyo, Japan

Shizuo Oi, M.D.
Tokyo, Japan

Harold Rekate, M.D.
Phoenix, Arizona

Henry W.S. Schroeder, M.D., Ph.D.
Greifswald, Germany

Mark M. Souweidane, M.D.
New York, New York

Pietro Spennato, M.D.
Naples, Italy

Gianpiero Tamburrini, M.D.
Rome, Italy

Charles Teo, M.D.
Sydney, Australia

Benjamin Warf, M.D.
Wilmington, Delaware

Samuel Tau Zymberg, M.D.
Sao Paulo, Brazil

Reprint requests:
Paolo Cappabianca, M.D.,
Department of Neurological Sciences,
Division of Neurosurgery,
Università degli Studi di
Napoli Federico II,
Via Pansini n 5,
Naples, Italy 80131.
Email: paolo.cappabianca@unina.it

Received, July 23, 2007.

Accepted, September 24, 2007.

ONLINE
DIGITAL
VIDEO

Application of Neuroendoscopy to Intraventricular Lesions

WE PRESENT AN overview of the history, development, technological advancements, current application, and future trends of cranial endoscopy. Neuroendoscopy provides a safe and effective management modality for the treatment of a variety of intracranial disorders, either tumoral or non-tumoral, congenital, developmental, and degenerative, and its knowledge, indications, and limits are fundamental for the armamentarium of the modern neurosurgeon.

KEY WORDS: Cranial base, Endoscope, Minimally invasive surgery, Neuroendoscopy, Skull base, Ventricular surgery

Neurosurgery 62[SHC Suppl 2]:SHC575–SHC598, 2008 DOI: 10.1227/01.NEU.0000297107.42131.DF

Intraventricular tumors and cysts are ideal lesions for the application of neuroendoscopy. Good visualization is possible due to their location inside the cerebrospinal fluid (CSF)-filled ventricular system; the often-associated obstruction of the CSF pathway and ventricular enlargement offer the possibility of working in large spaces. Moreover, with recent developments in neuroendoscopy coupled with framed stereotactic and frameless, computer-based stereotactic technologies, ventricular dilation is no longer an indispensable prerequisite.

As early as 1963, Guiot et al. (36) reported the use of ventriculoscopy in a patient with a colloid cyst. In 1973, Fukushima et al. (30) provided the first modern description of an endoscopic biopsy with the introduction of the ventriculofiberscope. The evolution of endoscopic techniques and improvement in adequacy of diagnosis have allowed us to dramatically change the prognosis and therapeutic regimen in pineal region tumors; today, neuroendoscopy is the preferred technique to achieve minimally invasive management of these lesions (64). The great advantages of neuroendoscopy over other biopsy techniques are that it allows visualization of ependymal surfaces to diagnose unsuspected metastases and, more importantly, it is possible to manage associated hydrocephalus via the same minimally invasive approach. By a combination of third ventriculostomies, septostomies, and stent placement, it is possible to reestablish patency of CSF pathways in several circumstances, including aqueductal stenosis, multiloculated hydrocephalus, and foramen of Monro stenosis. Neuroendoscopy, performed to establish diagnosis and cure hydrocephalus, can be the only invasive procedure for those tumors that do not require microsurgical resection such as germinomas or highly malignant gliomas; otherwise, neuroendoscopy can be followed by definitive surgical treatment. Neuro-oncologic application of neuroendoscopy includes endoscopic tumor biopsy (29, 31, 34, 54, 65, 69, 71, 76), the management of secondary hydrocephalus, and endoscopic intraventricular tumor resection (49, 79).

In selected cases, it is possible to achieve gross total removal of intraventricular tumors entirely with endoscopic techniques. The ideal tumor for endoscopic resection should reflect the following characteristics: moderate vascularity, soft consistency, small diameter (<2–3 cm [31]), associated hydrocephalus, low histological grade, and location inside the lateral ventricle (79). The list of tumors amenable to purely endoscopic resection is short. Several patients with colloid cysts and a small proportion of patients with other tumors such as subependymal giant cell astrocytomas, exophytic low-grade gliomas, central neurocytomas, small choroid plexus tumors, and purely intraventricular craniopharyngiomas may be candidates for this technique (2, 16, 31, 46, 79).

Colloid cysts are, in fact, the intraventricular lesions that have been most often managed using endoscopic treatments (1, 24, 49, 72, 73). The advantage of endoscopic surgery compared with microsurgery should be lower morbidity, shorter operative time, and shorter hospital stay. This has been documented only in cases of colloid cysts, whereas this observation is anecdotal for other tumors as a result of the low number of cases (49, 79).

This article offers a review and an update of the procedures that have been considered suitable for the application of neuroendoscopic techniques in the treatment of intra- or paraventricular lesions. The intent is to offer a basic platform for future ideas, applications, and developments. Time and, we hope, prospective studies will validate some of these preliminary experiences.

Historical Vignette

(see video at web site)

Since the first publications by Dandy (20a) (who coined the term "ventriculoscopy"), Volkmann in 1922, Mixter (57a) in 1923, and Fay and Grant (27a) in 1924, ventriculoscopy was performed only by a small number of authors, always for the same indication: treatment of hydrocephalus either communicating by coagulation of the choroid plexus (approximately 50 cases published in 1963) or obstructive by ventriculocisternostomy at the level of the floor of the third ventricle (10 cases published in 1963) (36). At the end of the 1950s, use of the endoscopic technique was just beginning. The visual quality was poor, primarily because of a weak light from a small lamp located at the distal end of the endoscope. During this period, Gerard Guiot joined Jacques Vulmiere's team at the National Scientific Research Center of the Institute of Optics of Paris, which had developed a "universal endoscope." The principle of this endoscope resided in the development of an external light source (known today as a cold light generator) of variable intensity, which concentrated, by an adapted device, the radiation at the proximal end of a rectilinear, transparent, silica stem after having crossed an infrared filter to withdraw its heating effects. The light traveled along this stem, retaining at least 88% of its initial intensity. This innovation made it possible to increase the light intensity of the old endoscopes by several hundreds of times. Guiot used an endoscope that was 8.2 mm in diameter and 2.0 cm in length, with a sheath of 9.1 mm outer diameter that crossed a steering joint resting on the level of the burr hole and maintained in place by an external articulated arm. Using this system, Guiot was the first to attain photographs and endoscopic films of the ventricular cavities with a nonprofessional camera, wrapped in a sterile field; the surgeon's head was also covered with a sterile hood and glasses.

The indications for third ventriculostomy were extended to the treatment of the hydrocephalus of a child (under 1 yr of age), which is still a delicate matter of discussion today. The treatment of colloid cysts of the third ventricle did not include removal because of the lack of dedicated instrumentation that is available today.

The contribution of Gerard Guiot to the development of the transsphenoidal approach to pituitary adenomas is well-known (35). A lesser-known work is his association of the transsphenoidal approach to intracranial endoscopy, which allowed him to perform some procedures under endoscopic control, including removal of a pituitary adenoma, removal of a cranial base tumor with sphenoidal extension, and evacuation of an intrasellar cyst. Along with these experiences, he also obtained nice endoscopic views of the anterior part of the circle of Willis.

This film demonstrates the prominence of Gerard Guiot in the development of neuroendoscopy. Its dynamism is still resonant, and incites us to continue his work to discover new developments of neuroendoscopy.

Neoplastic Lesions of the Lateral Ventricle

General Indications and Limitations

Neuroendoscopic techniques were initially proposed for intraventricular lesions that cause hydrocephalus, where large ventricles allow easier navigation. These techniques are progressively drifting toward image-guided approaches for patients with normal ventricles and paraventricular tumors; they are used not only to perform biopsies, but also to attempt complete endoscopic resections. The decision to biopsy or to attempt radical resection is primarily based on clinical considerations and is secondarily dictated by tumor location, size, and uni- or multifocal nature. In general, a lesion can be considered suitable for endoscopic resection if it is unique, bulges into the ventricle (possibly with a small implant base), has a diameter not larger than 2 cm without significant vascular images, and is accessible through a straight track, which allows the use of a rod-lens endoscope with a large operative channel by a neurosurgeon trained in neuroendoscopic surgery. If the lesion is larger than 2 cm, multifocal with subependymal location without intraventricular bulging, or can be reached only with a steerable endoscope (i.e., posterosuperior part of the third ventricle), then it is considered suitable for a biopsy if clinically indicated.

Endoscopic Biopsy of Intraventricular and Paraventricular Tumors

(see video at web site)

Patient Selection

A more diffuse indication for the use of neuroendoscopy in the case of an intraventricular lesion is to perform a biopsy (31, 53, 62, 80, 87). The main advantage of endoscopic biopsy is the direct view of the lesion, which allows for choice of the biopsy area, and therefore improves the diagnostic efficacy, the possibility of hemostasis, and the choice of a safer trajectory to protect the normal anatomic structures. Endoscopy permits the simultaneous treatment of associated hydrocephalus by means of a third ventriculostomy (endoscopic third ventriculostomy [ETV]) or septostomy. In patients with clear anatomic landmarks and large ventricles, freehand endoscopic biopsy is currently an alternative to stereotaxy. In patients with small ventricles, endoscopy can be associated with neuronavigation or, eventually, with stereotaxy. For paraventricular parenchymal tumors (i.e., thalamomesencephalic or basal ganglia), an endoscopic biopsy can be performed if there is an intraventricular extension of the lesion. Both rigid and flexible endoscopes are suitable for biopsy and ETV through a single trajectory.

Endoscopic Technique

(see video at web site)

When approaching the anterior two-thirds of the lateral and third ventricle through a frontal precoronal burr hole, a rigid endoscope or fiberscope allows better vision and more efficient surgical maneuvers with superior instruments. For the pineal region, we prefer a steerable endoscope introduced through a coronal burr hole to assure safer maneuvers for biopsy and ETV. Only in one case of trigonal tumor was a transoccipital approach used. Whenever possible, we suggest obtaining at least three biopsy specimens, from different areas, controlling the frequent minor oozing with irrigation and/or mild compression with a balloon and, only in exceptional cases, with low-power coagulation. When an ETV is necessary, biopsy should be performed first to prevent blood from reaching the interpeduncular cistern. In our experience with 41 neuroendoscopic biopsies, a histological diagnosis was obtained for 37 patients (90%). Lesions were localized in the third ventricle (29 patients), pineal region (14 patients), thalamomesencephalic region (11 patients), and lateral ventricle and foramen of Monro (6 patients). Of 19 patients treated via ETV, hydrocephalus resolved in 15 patients. Diagnosis was positive for low-grade gliomas (nine patients), two lymphomas, one neurocytoma, one epidermoid, seven craniopharyngiomas, one cavernoma, four germinomas, three pineocytomas, one pineoblastoma, six high-grade gliomas, one teratoma, and one pineal cyst. In patients with craniopharyngiomas, the endoscopic procedure also allowed the aspiration of the cyst and a cyst–cisternostomy. Ten patients underwent a subsequent microsurgery, whereas in 11 patients, radiotherapy was performed. Complications observed were transient obstruction of a preexisting shunt in one patient and a major intraventricular hemorrhage, which required surgical evacuation, in another patient. No mortality or permanent morbidity was observed in this series. Some authors conclude that endoscopic biopsy of intraventricular tumors is associated with a low hemorrhagic complication rate (53); others relate that neuroendoscopy is a safe, minimally invasive biopsy approach for intra- and paraventricular (with intraventricular extension) tumors with a highly successful diagnostic rate (31, 53, 62, 87). The risk of hemorrhagic and potentially fatal complications after tumor biopsy is nevertheless present (67) and should be considered in the algorithm of patient treatment.

Complete Endoscopic Removal of Intra- and Paraventricular Tumors

Patient Selection

(see video at web site)

Complete endoscopic resection of paraventricular tumors is not always advisable and is dependent on clinical history as well as the tumor's relationship to other important structures such as the fornix or thalamostriate vein (4, 21, 27). When the base of attachment appears to permit complete removal, then the approach trajectory, equipment, and the surgeon's skills will determine the completeness of the resection.

Endoscopic Technique

The trajectory is controlled by use of frameless stereotactic imaging. This trajectory to the paraventricular mass can be through the ipsilateral or, sometimes, the contralateral ventricle. Most tumors are approached from a single burr hole on the ipsilateral side approximately 3 cm off the midline near the coronal suture. The burr hole must be large enough to accommodate a wand-like motion of the scope. This permits the surgeon to see around the tumor. Frequent movement of the scope is required for rapid tumor resection and most mechanical scope holders hinder rather than help in this regard; an assistant is the best scope holder. Once the burr hole is created, the endoscope cannula is guided by a computer to the tumor, but it is positioned far enough away so that critical intraventricular elements can be observed.

We usually use an 8.9-mm cannula for tumor resection. This permits the use of a scope with a 4-mm viewing port and an instrument port large enough to accommodate the insertion of 2-mm-diameter instruments. If one needed to work in the third ventricle, then a smaller-diameter cannula with smaller instruments would be used to avoid injury to the fornix, unless the foramen of Monro was unusually large. The surgical resection is aided by use of these instruments, which are large enough to quickly remove significant portions of a tumor with each "bite." Because many of these tumors are benign and relatively avascular, removing large portions of the tumor is safe. However, to prevent substantial bleeding, which can obscure the surgeon's vision, an opposable bipolar instrument and forceful irrigation from the tip of the endoscope are very important. Forceful irrigation can clear stubborn bleeding from the area of interest, making it easier to locate and coagulate the bleeding site. The endoscopic opposable bipolar instrument functions like those commonly used in neurosurgery and attaches to the same power generator. The offending vessel can be grasped and cauterized. Preemptive coagulation of the tumor surface or the nearby choroid plexus can also prevent unwanted bleeding, which would otherwise slow the surgery.

Should bleeding be a persistent problem, it is possible to insert a small cotton pad down the barrel of the endoscope cannula. The endoscope is removed from the cannula and the pad is loaded into the cannula, which can be forced into a position of tamponade using the viewing end of the endoscope. A short period of pressure is usually followed with hemostasis. The attached string allows for easy retrieval of the pad when the scope is again removed from the cannula. If careful attention is paid to bleeding and piece-by-piece excision, the tumor can be completely removed.

Complete Endoscopic Removal of Intra- and Paraventricular Tumors

(see video at web site)

Patient Selection

It is impossible to preoperatively determine the exact size limit of a tumor for an effective endoscopic resection. In gen-

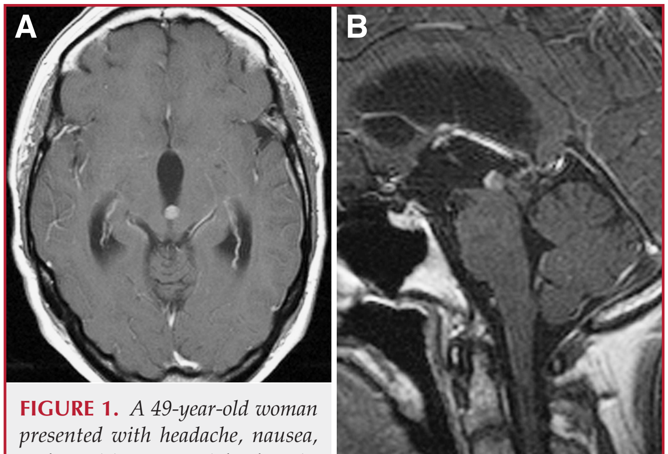

FIGURE 1. *A 49-year-old woman presented with headache, nausea, and vomiting. T1-weighted sagittal (**A**) and axial (**B**) magnetic resonance imaging (MRI) scans revealed a small, contrast-enhancing lesion obstructing the aqueduct and thereby inducing triventricular hydrocephalus.*

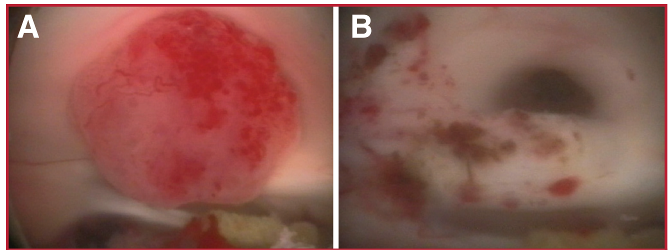

FIGURE 2. **A**, *the lesion was endoscopically approached through the right foramen of Monro.* **B**, *complete lesion removal.*

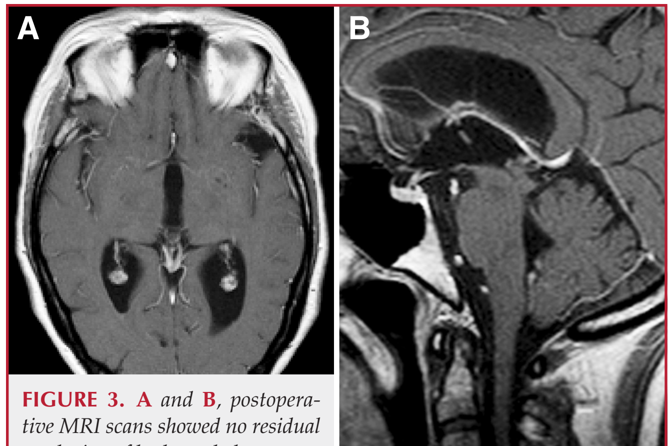

FIGURE 3. **A** *and* **B**, *postoperative MRI scans showed no residual resolution of hydrocephalus.*

eral, a solid tumor should not exceed 2 cm in diameter (*Fig. 1*). Cystic lesions may be treated even if they are larger. The endoscopic removal may become time-consuming and ineffective if the tumor is too large and too firm. The benefit of the minimally invasive approach is then outweighed by the duration of the operation, and one should not hesitate to change to an open microsurgical operation. Using a small keyhole approach and endoscope-assisted microsurgical techniques, an effective and minimally invasive tumor removal without extensive brain dissection is feasible (68).

Endoscopic Technique

The general principle of the endoscopic treatment of intra- and paraventricular tumors is interruption of the blood supply to the tumor and subsequent tumor debulking. In general, a piecemeal resection is performed; however, in some tumors, it is possible to detach the lesion from the surrounding brain and remove it *in toto*. After resection, a careful hemostasis is crucial for avoiding rebleeding (*Fig. 2*).

With improvement of experience, it is possible to remove selected tumors completely with a purely endoscopic technique (*Fig. 3*). Even highly vascularized lesions such as cavernomas can be endoscopically extirpated (31).

A major drawback of endoscopic tumor removal through the working channel of an endoscope is a lack of dexterity and reduced ability for bimanual dissection. The separation of the tissues is easier when performed bimanually under the microscope. However, when using two working channels, a kind of bimanual dissection can be achieved. Instruments that allow effective tissue removal and simultaneous hemostasis such as bipolar tumor forceps can be extremely useful. Ultrasonic aspirators usable through the working channel of ventriculoscopes have been developed, but their value in endoscopic tumor resection remains to be determined. The use of a second working portal enabling the insertion of larger instruments and thus accelerating tumor removal has been advocated because this would allow better bimanual dissection (41). However, this has not yet received widespread application. Theoretically, a separate insertion of an ultrasonic aspirator through a second burr hole might be useful for selected tumors. To date, we have simply switched over to a microsurgical technique when we felt uncomfortable with the one-portal endoscopic technique.

In conclusion, the endoscopic removal of intra- and paraventricular tumors is an evolving neurosurgical technique that has already replaced the standard microsurgical approach to selected tumors. The endoscopic approach is less invasive and similarly effective when compared with the microsurgical technique. With additional development of endoscopic instrumentation, the application of the technique will expand to include larger tumors, which are still a domain of microsurgery.

Endoscope-controlled Removal

(see video at web site)

Illustrative Case

A 7-year-old boy was diagnosed in early childhood with tuberous sclerosis and autism. He was followed regularly with cerebral magnetic resonance imaging (MRI) scans. Four consecutive scans revealed growth of a subependymal lesion in the right occipital paraventricular region. At another institution, radiotherapy was recommended, but the parents wanted a second opinion. Because the lesion was most likely a subependymal giant cell astrocytoma and, despite the absence of hydrocephalus, could be approached with acceptable risk, removal of the lesion was proposed, and the parents consented to this option.

On the day of surgery, an MRI scan was obtained for electromagnetic navigation. An electromagnetic marker was fixed to the upper frontal region and, with the patient initially in the supine position, the navigation referencing was performed. The patient was then repositioned to a prone position on the electromagnetic headrest while the head was fixed in a vacuum beanbag.

A 5-cm straight incision was made in the right occipital region and a 2 × 2-cm circular bone flap was created. After we opened the dura and coagulated of the arachnoid, a small corticotomy was made. A cylindrical balloon catheter was placed into the occipital horn and, over 30 minutes, the balloon was slowly inflated, creating a cortical channel to the ventricle. After removal of the balloon catheter, a 5-mm straight retractor was placed into the channel and next to this, the 30-degree endoscope (Minop System; Aesculap Inc., Tuttlingen, Germany) was introduced into the occipital ventricle. The tumor was immediately visible and, with the microinstruments adjacent to the endoscope, the tumor was removed completely with the help of suction, bipolar coagulation, and grasping forceps. Hemostasis at the subependymal area of attachment was achieved by bipolar coagulation and application of FloSeal (Baxter Bioscience, Vienna, Austria). The ventricles were rinsed with warm Ringer's solution to clear all debris. The dura was closed with interrupted sutures and sealed watertight with DuraSeal (Confluent Surgical, Waltham, MA). The bone flap was replaced and the wound closed in layers. Postoperatively, the patient showed no neurological deficits.

Endoscopic Surgery of Intraventricular Brain Tumors in Patients without Ventriculomegaly

(see video at web site)

Patient Selection

Endoscopic surgery for patients without hydrocephalus is usually avoided because of the purported difficulty with ventricular cannulation and intraventricular navigation. However, our recent experience (75) with this type of patient highlights the importance of several technical features, including disciplined patient selection, navigational guidance, and ventricular insufflation.

Performing endoscopic surgery in normal-sized ventricles should be considered only when the surgeon has significant experience in endoscopic and stereotactic techniques. Another mandate is that, on preoperative MRI scans, the tumor must have an intraventricular extension rather than a subependymal location. Tumors outside of the ventricle with minimal to no deformation of the ependymal surface are considered poor candidates for endoscopic management.

Because of the limited space in which to manipulate the endoscope in patients without hydrocephalus, anatomic position of the tumor must be taken into consideration. Most locations within the lateral ventricle will lend themselves to endoscopic approaches. Lesions situated posterior to the aqueduct (inclusive of pineal region tumors) are predictably difficult, if not dangerous, to approach in the absence of hydrocephalus with the aim of complete removal, whereas modified and dedicated endoscopes used in combination with a careful choice of the entry point location would allow an endoscopic approach for endoscopic biopsy if clinically indicated.

Endoscopic Technique

Patient position is dictated by the preferred entry site. The final determination is made at the time of surgery with navigational guidance. The head should always be elevated above a horizontal plane in an effort to minimize CSF egress. An entry site is selected that offers the most direct intraventricular, linear route to the target. With respect to laterality, the entry is placed on the nondominant side, the exception being eccentric hypothalamic lesions, which are best targeted using a contralateral approach.

Frameless stereotactic guidance is recommended for patients without hydrocephalus. The endoscope sheath or a standard ventricular catheter (outside diameter, 1.7 mm) can be registered using an optically guided system (*Fig. 4A*). Initial ventricular cannulation can be accomplished using stereotactic guidance with a ventricular catheter rather than the endoscopic sheath, owing to the catheter's smaller caliber and the need for ventricular insufflation. CSF can be collected if indicated for

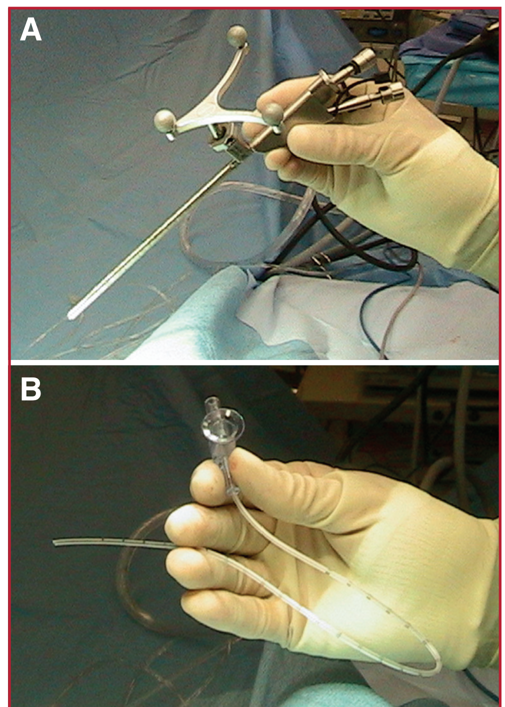

FIGURE 4. A, *a solid-lens endoscope and sheath were integrated into an optically guided stereotactic system by way of an attached array of reflecting spheres. A 6-French suction device was used for tumor aspiration. The clear plastic design is useful for assessing the strength and direction of suctioning, and it protects against inadvertent aspiration of choroid plexus.* **B**, *the catheter tip is cut to an angle to remove the fenestrations.*

cytological and biochemical analyses. Once CSF return confirms an intraventricular position, slow injection of lactated Ringer's solution (5–10 mL) accomplishes a gradual insufflation of the ventricles. During insufflation, attention to the patient's hemodynamic status is necessary to ensure that no relative bradycardia occurs secondary to raised intracranial pressure. After controlled insufflation, the access catheter is replaced with the endoscopic sheath.

Continuous irrigation maintains a clear medium of image transmission and ventricular patency. A constant purge needs to be used throughout the procedure to avoid overinsufflating the ventricular system and elevating the intracranial pressure. The simplest method for accomplishing CSF egress involves maintaining patency of a portal separate from the working channel or using a system in which the diameter of the sheath is greater than the endoscope. This method thus maintains an intracranial pressure that cannot exceed the pressure of a fluid column equal to the length of the endoscope (15 cmH_2O).

For patients undergoing tumor biopsy, sampling of the tumor mass is performed by selecting a relatively avascular portion of the tumor. Cupped biopsy forceps are used without any preceding coagulation. Typically, small venous bleeding is subsequent to the diagnostic sampling and is controlled with directed irrigation. In some situations, a 3-French embolectomy balloon can be inflated and used for tamponade. In all cases of tumor biopsy, a frozen specimen should be analyzed to confirm that representative tissue was obtained before wound closure. When small tumors are to be removed, it is prudent to generously coagulate the tumor before attempting a resection. After generous coagulation of the tumor surface, a 6-French endotracheal suction catheter is the primary means for removing tumor tissue with a pulsed technique. The graduated catheter is made of transparent plastic with a self-regulated aperture (Kendall Co., Mansfield, MA). The suction catheter is modified by removing the distal fenestrations with an angled cut (*Fig. 4B*). The beveled tip is useful for perforating tumor capsules or solid tumor tissue. The importance of the translucent feature rests in the ability to visualize aspirated material. This feature can be used to gauge effectiveness of tissue removal and thus direct optimal placement of the catheter tip. Additionally, the translucent nature of the catheter offers the ability to identify when tissue such as choroid plexus is being suctioned, and one can thus regulate when aspiration should be adjusted or discontinued. Aspiration is only applied once the catheter tip is firmly and completely embedded within the tumor tissue. The degree of suction is regulated to preferentially act on friable tumor tissue rather than the more solid parenchymal interface. This maneuver is alternated with blunt dissection to separate the tumor surface from adjacent ependymal tissue. An example of solid tumor removal is illustrated in *Video 1*. The use of externalized ventricular drainage should be dictated on an individual basis depending on the degree of intraventricular hemorrhage.

In conclusion, the lack of hydrocephalus in patients with intraventricular tumors does not alone preclude endoscopic management. The procedure in this clinical setting can be effective in achieving the intended surgical goal and on a retrospective review of our initial series of patients, it seems not to significantly differ from the results in patients with hydrocephalus.

Intraventricular Nontumoral Lesions: Neurocysticercosis

(see video at web site)

Pathophysiology of the Disease

Neurocysticercosis is a frequent parasitic disease (50 million people are infected on a worldwide basis, especially in South America, India, China, and the Far East) caused by infection with the larval stage, the *Cysticercus cellulosae*, of the cestode intestinal tapeworm *Taenia solium*. When located within the ventricles or basal cisterns, secondary vesicles may form from its walls and appear as a grape cluster (*Cysticercus racemosus*) (13). The infestation of the ventricles is attributed to active passage of the embryo through the capillaries of the choroid plexus. Intraventricular involvement occurs in 7 to 33% of cases, and is most common in the fourth ventricle. Intraventricular cysts can cause hydrocephalus and are potentially fatal. They are not always amenable to medical management, and usually require surgical intervention for either cyst removal or CSF shunting (6).

Patient Selection

Because definitive medical therapy with antiparasitic agents (albendazole and praziquantel) demands time, there is a high risk of acute intracranial pressure elevation during the clinical treatment period (6). CSF shunting is burdened by a high shunt-dysfunction rate (30–67%) and high mortality rates (17). For these reasons, endoscopic approaches for intraventricular neurocysticercosis have been described in recent years. Free intraventricular cysts, even those located in the third and fourth ventricles, are easily removed by endoscopy (*Fig. 3*). Ventricular cysts appear on computed tomographic (CT) scans as lesions that distort the anatomy of the ventricular system and cause obstructive hydrocephalus. These lesions are usually isodense to CSF and are not well viewed on CT. MRI, however, better detects the ventricular cysts because the scolex can be visualized. Ependymitis, identified on contrast-enhanced MRI scans, is a relative contraindication for surgical removal of the cysts.

Endoscopic Technique

In the absence of ependymitis, surgeons must be aware that these cysts may shift position frequently and move from one region to another, thereby changing the surgical planning. Performing early imaging study is a wise measure to prevent cysts from being overlooked during surgery. Cyst ruptures during the procedure are common and are not associated with additional ventriculitis. Ventricular loculations can be managed by endoscopic fenestration and placement of a single shunt system. ETV is an excellent option when obstructive hydrocephalus is detected at the level of aqueduct or fourth ventricle and is sometimes helpful in cases where the etiology is not clear. Even in parenchymal or cisternal tumoral forms, endoscopy is a useful tool that allows removal of cysts and inspection of the remaining cavity (8). Of 600 patients who underwent endoscopic procedures in our institution, the association of hydrocephalus and neurocysticercosis was identified in 36 patients (6%).

Regarding the endoscopic approach to fourth ventricle cysts, great care must be taken to preserve the many important nervous structures surrounding the aqueduct. We propose the frontal transforaminal transaqueductal route for selected patients. A cysticercus in the fourth ventricle must be carefully evaluated after a detailed MRI study is performed for hydrocephalus, foramen of Monro, and aqueductal dilation and no ependymal enhancement (7). This procedure allows for cyst removal and hydrocephalus treatment , freeing the patient from shunt procedures.

Endoscopic Removal of Intraventricular Hematoma

(see video at web site)

Patient Selection

The primary aim of the acute management of intraventricular hematoma (IVH) is the faster removal of intraventricular blood and the rapid reversal of ventricular dilation with normalization of intracranial pressure. The conventional treatment of IVH consists of external ventricular drainage with or without fibrinolysis. The method, however, is not without its drawbacks; its efficacy is not immediate, and satisfactory drainage of blood could take several days (18). Bilateral craniotomy and microsurgical evacuation are obviously limited to the aspiration of the casting cloths of the lateral ventricles and, partially, of the third ventricle (47).

All the goals of effective IVH treatment may be achieved using a neuroendoscopic approach, possibly with a lower complication rate than that associated with external ventricular drainage. Intraventricular blood clots casting the ventricles are less consistent than intraparenchymal ones, and they can be reached throughout the ventricular system with a flexible scope (50–52). The use of combined intravascular embolization and endoscopy should be considered among the treatment options in patients presenting with IVHs from bleeding aneurysms, to assure fast and safe management of both the IVH and the ruptured aneurysms (*Fig. 5*) (50).

Endoscopic Technique

For removal of clots from all of the ventricles, flexible endoscopes (external diameter ranging from 2.5–3.9 mm) used with a freehand technique should be preferred (39). The working channel is 1.2 mm in diameter and can be used as a vacuum without any additional insertion of catheters.

Access is achieved precoronally via a 12-mm burr hole that is usually monolateral and bilateral only when deemed necessary. The frontal horn is incannulated with a 15-French peelaway sheath, and the endoscope is introduced with this guide to protect the brain during the frequent insertions and withdrawals of the scope.

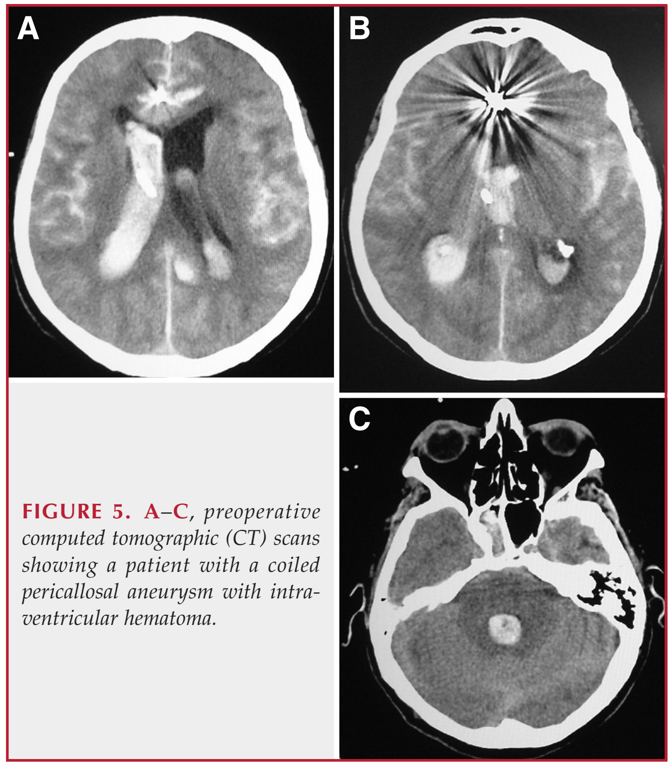

FIGURE 5. A–C, *preoperative computed tomographic (CT) scans showing a patient with a coiled pericallosal aneurysm with intraventricular hematoma.*

Once the endoscope reaches the inundated ventricle, the contact of the optics with blood renders the system completely blind, with the color varying from dark red to black. The tip of the scope is held at the ependymal margin to avoid blind maneuvers that can damage structures of the ventricle and, particularly, of the fornices. A vigorous intermittent manual aspiration is started using a syringe connected to the operating channel of the endoscope. This action breaks down the fragile clots and is perceived by the fingers of the surgeon handing the scope as a sort of gurgling accompanied by reddish flashing on the monitor. The aspiration is alternated with irrigation with Ringer's solution and is promptly stopped when the dark red changes to a whitish color, which is a sign of potential contact with nervous structures. This preliminary action allows a clot-free chamber to exist, which permits some, indispensable, vision (*Fig. 6A*). The choroidal plexus and foramen of Munro are identified, the instrument is safely advanced through them in the third ventricle (*Fig. 6B*), and gentle aspiration and irrigation are reiterated. Freeing the third ventricle opens the path to the aqueduct and to the fourth ventricle just posteriorly by deflecting the flexible scope. In the fourth ventricle, maneuvers of aspiration and, particularly, irrigation should be performed more carefully, because the endoscope fills the entire diameter of the aqueduct, and potentially dangerous hypertension of the trapped rhomboid fossa might be easily caused by a large amount of Ringer's solution. The foramen of Magendie is identified and, if obstructed, it is possibly unclogged (*Fig. 6C*). Finally, as the endoscope is withdrawn, stirred posteriorly toward the occip-

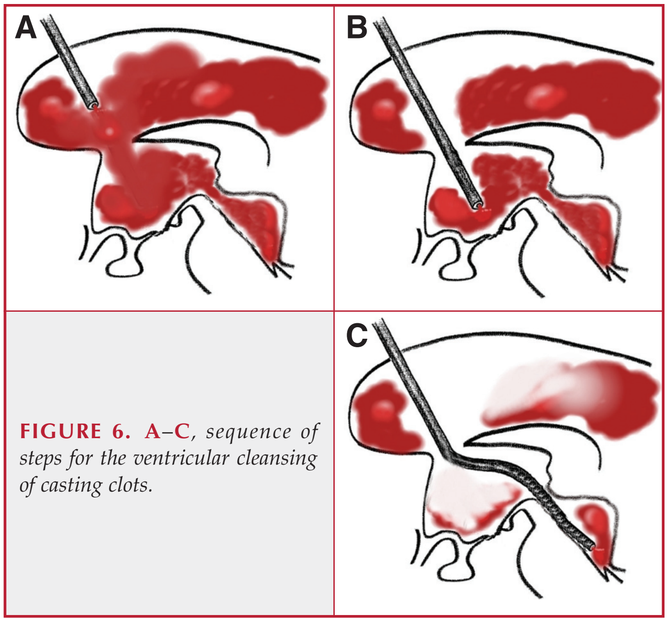

FIGURE 6. A–C, *sequence of steps for the ventricular cleansing of casting clots.*

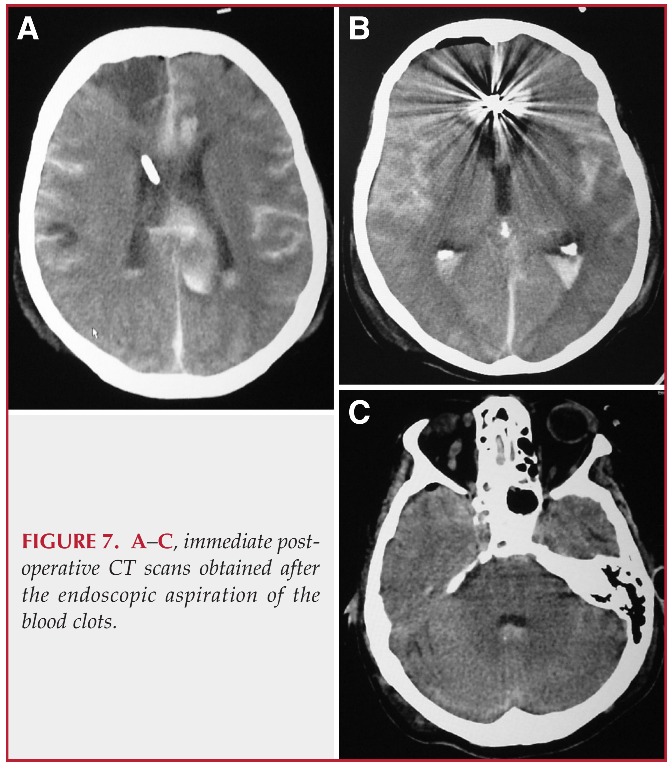

FIGURE 7. A–C, *immediate postoperative CT scans obtained after the endoscopic aspiration of the blood clots.*

ital horn and the trigone and anteriorly toward the frontal horns in the lateral ventricle to complete the aspiration of clots. In our experience, most of the time is spent in the lateral ventricles (30 seconds each). Clearing of clots of the third and fourth ventricles take no more than 5 seconds each.

At the end of the procedure, an external ventricular catheter may be placed both for intracranial pressure monitoring and for drainage (with a constant gradient of +15 mmHg) for several days. An immediate postoperative CT scan is performed (*Fig. 7*) and then reiterated if necessary in subsequent days.

Using flexible instruments that are managed with the freehand technique offers less clear observation than rigid instruments; however, flexible instruments allow safe navigation of the third ventricle, down to the fourth ventricle and through the aqueduct, with complete clearance of clots. The complete liberation of the aqueduct and fourth ventricle represents an important feature of this treatment in immediately reestablishing the physiological CSF dynamics (51, 52).

Lateral Ventricular/Paraventricular Lesions: Intracerebral Hematoma

(see video at web site)

Patient Selection

Endoscopic evacuation of intracerebral hematoma is indicated for spontaneous or hypertensive intracerebral hemorrhage excluding organic diseases such as aneurysm and vascular anomaly, which can be the source of hemorrhage. To be specific, we indicate endoscopic surgery for putaminal hemorrhage, thalamic hemorrhage, and subcortical hemorrhage that is 20 mL or more in volume, and for cerebellar hemorrhage that is 15 mL or more in volume, with deterioration of consciousness. We assume that thalamic hemorrhage with ventricular rupture associated with obstructive hydrocephalus is, in particular, a good indication. We indicate ultra-early endoscopic surgery for hemorrhage with a volume of 30 mL or more, and we are practicing ultra-early treatment for hemorrhage that causes impending herniation (60, 61). This procedure can allow a more effective hematoma removal in less time (9) without the complications and additional brain injury related with a traditional craniotomy approach.

Surgical Instruments

We developed and produced a transparent guiding sheath for endoscopic hematoma evacuation (HEG-0810P/HEG-810M; Machida Endoscope Co. Ltd., Tokyo, Japan). It is made of acrylic resin, and it measures 8, 6, and 120 mm in outer diameter, inner diameter, and length, respectively (*Fig. 8A*). A round-tipped stylet is made of stainless steel and measures 5.9 and 140 mm in outer diameter and length, respectively (*Fig. 8B*). An angled rigid endoscope, 2.7 mm in outer diameter, is used (endoscope for assisting microscopic surgery; MS-1000R; Machida Endoscope Co. Ltd.). We manufactured an insulator-coated suction tube, 2 or 2.5 mm, for hematoma evacuation and electric coagulation (Fujita Medical Instrument, Tokyo, Japan) (*Fig. 8C*). We developed and produced a transparent cap attachable to a flexible endoscope for the removal of intraventricular hematoma (Machida Seisakusho, Tokyo, Japan) (*Fig. 8D*).

Endoscopic Technique

The schematic illustration of our procedure is shown in *Figure 9*. Surgical procedures can be performed under local anesthesia except for patients with severe airway obstruction who require

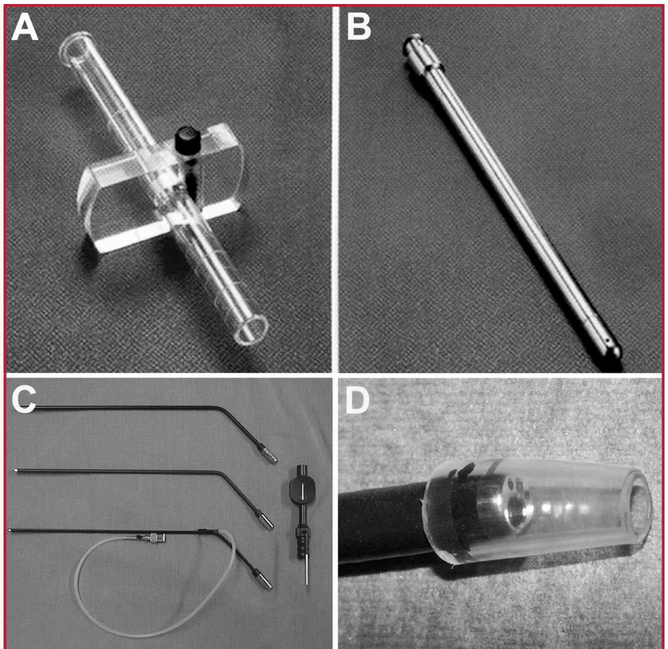

FIGURE 8. **A**, *a transparent guiding sheath is used for endoscopic hematoma evacuation.* **B**, *the sheath stylet.* **C**, *suction tubes for endoscopic hematoma evacuation.* **D**, *transparent cap attached to a flexible endoscope.*

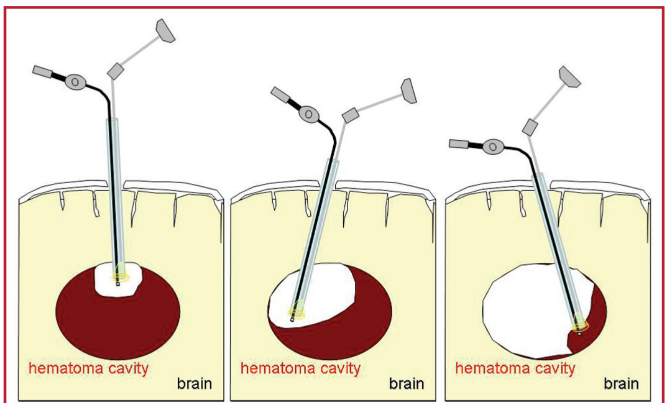

FIGURE 9. *A rigid endoscope is inserted through the sheath and the hematoma is evacuated with a suction tube (***A***). The direction and the depth of the sheath is gently changed to inspect all aspects of the hematoma cavity and evacuate the hematoma (***B***). Redirecting the sheath enables access to the entire surface of the hematoma cavity, including the bleeding points. Freehand surgery without fixing an endoscope and a sheath to a frame facilitates three-dimensional operation (***C***).*

endotracheal intubation. A patient with putaminal or thalamic hemorrhage is usually placed in a supine position, and a patient with subcortical or cerebellar hemorrhage is placed in a lateral position to set the surgical field on top. A 4-cm linear skin incision and a 12-mm-diameter burr hole opening are made, and the dura is incised in a cruciate fashion. A burr hole-type echo-guided test puncture is performed first with a puncture to check the direction and depth of the hematoma, and then a transparent sheath with a stylet is inserted into the hematoma cavity. The stylet is removed, and the sheath is held gently by an assistant. A 2.7-mm rigid endoscope is inserted through the sheath, and the hematoma is evacuated with a suction tube. The transparent sheath improves the visualization of the border between the brain parenchyma and the hematoma. The hematoma is removed from near to far with the meticulous movement of the sheath and the continuous referral to the hematoma–brain border. When bleeding from a perforating artery occurs, a suction tube is placed at the bleeding point for suction and also for hemostasis by electrical coagulation. When the evacuation is almost complete, the sheath is removed, the burr hole is packed with bone dust, and the wound is closed in layers. For intraventricular hemorrhage, a sheath is inserted into the anterior horn of the lateral ventricle and the hematoma on the same side is evacuated. For intraventricular hemorrhage located at the posterior horn of the lateral ventricle, a transparent cap is applied to the end of a flexible endoscope, and the hematoma is evacuated with a 5-French catheter, which is inserted through a forceps channel and is 1 to 2 mm out of the transparent cap. In the evacuation of the hematoma in the contralateral lateral ventricle, the septum pellucidum is perforated, a sheath is advanced through the stoma, and the hematoma is removed. In the evacuation of the hematoma in the third ventricle, a sheath is advanced to the foramen of Monro through which the hematoma is removed. For thalamic hemorrhage with ventricular rupture, the hematoma in the lateral ventricle is evacuated first, a sheath is advanced through the rupture point, and then the hematoma in the thalamus is removed. Video of this endoscopic surgery of the left putaminal hemorrhage (*Fig. 10*) is presented.

The burr-hole approach under local anesthesia and the simple surgical instrumentation enable ultra-early surgery in patients for whom standard surgical treatment is controversial, because cerebral herniation may become irreversible during the waiting period for surgery. We have performed this surgical procedure in 150 patients with intracerebral or intraventricular hemorrhage thus far, among whom 86 patients had putaminal hemorrhage, 15 had thalamic hemorrhage, 16 had subcortical hemorrhage, 16 had cerebellar hemorrhage, and 17 had intraventricular hemorrhage. The mean volume of hematoma was 50 mL (range, 15–130 mL), the mean duration of surgery was 63 minutes, and the mean hematoma reduction rate was 96% (range, 86–100%). No postoperative rebleeding was identified on a CT scan for any of the 150 patients except for one individual with postoperative acute subdural hematoma.

Choroid Plexus Cauterization in the Treatment of Hydrocephalus in Developing Countries

(see video at web site)

Patient Selection

In establishing a center for pediatric neurosurgery in rural Uganda, elucidating the best management of hydrocephalus in infants within this context proved to be the biggest challenge (83, 84). ETV proved very successful in avoiding shunt dependency

FIGURE 10. *The skin incision for the minipterional approach.*

for children older than 1 year of age regardless of the etiology of hydrocephalus (80% success overall), but the result in those younger than 1 year of age was not nearly as good (47% success). The best result for these infants was among those with congenital aqueductal obstruction (54% success) and postinfectious aqueductal obstruction (61% success). The success rate in other infants (those with congenital or postinfectious hydrocephalus and a patent aqueduct and those with myelomeningocele) was 20 to 40%. The hypothesis that underdeveloped extra-axial CSF circulation and absorption capacity contributed to the inferior result of ETV in young infants led to the speculation that a reduction in the rate of CSF production by choroid plexus cauterization (CPC) at the time of the ETV might be helpful. It was hoped that reducing the rate of CSF production in the face of impaired absorption would help the maturing system accommodate to the new efflux of CSF through the ventriculocisternostomy.

CPC had not previously been attempted in combination with ETV. The unselected addition of CPC to ETV in every case was evaluated prospectively and compared with the results previously obtained with ETV alone (3). The ETV-CPC combined procedure was significantly superior to ETV alone for infants younger than 1 year of age (66% success compared with 47%, $P < 0.001$) (83, 84).

Endoscopic Technique

After the ETV, attention is turned to the CPC. Using a 3.7-mm flexible steerable neuroendoscope (Karl Storz Co., Tuttlingen, Germany), beginning at the foramen of Monro and gradually moving posteriorly, the choroid plexus of the lateral ventricle is thoroughly cauterized using Bugby wire and low-voltage monopolar coagulating current (*Fig. 11A*). In cases of severe ventriculomegaly, a portion of the choroid plexus in the anterior roof of the third ventricle is often available for cauterization as well. Care is taken to avoid injury to the thalamostriate and internal cerebral veins or ependymal surfaces. Special attention is paid to the complete coagulation of all vessels within the plexus, including the superior choroidal vein along its entire length (*Fig. 11B*). At the level of the atrium, the glomus portion of the choroid plexus is thoroughly cauterized. Then, passing the scope posterior to the thalamus, its tip is flexed and turned to direct the procedure along the choroid plexus of the temporal horn, which is then cauterized in similar fashion beginning at its anterior extreme and advancing posteriorly along its length (*Fig. 12*). Cautery is continued until all visible choroid plexus has been coagulated and shriveled. For cases in which the septum pellucidum is intact, a septostomy is performed superior to the posterior edge of the foramen of Monro to gain access to the contralateral choroid plexus, where the same procedure is carried out in the left lateral ventricle. Uncommonly, bleeding (usually venous) may be encountered from the choroid plexus. In such cases, it is more efficiently controlled by tamponading it with the Bugby wire while gently irrigating for a couple of minutes until it stops. The bilateral CPC typically adds from 20 to 30 minutes to the entire procedure. The preliminary results in an East African pediatric population are encouraging and warrant further studies to verify whether the indications for this technique can be extended to infants with other forms of hydrocephalus.

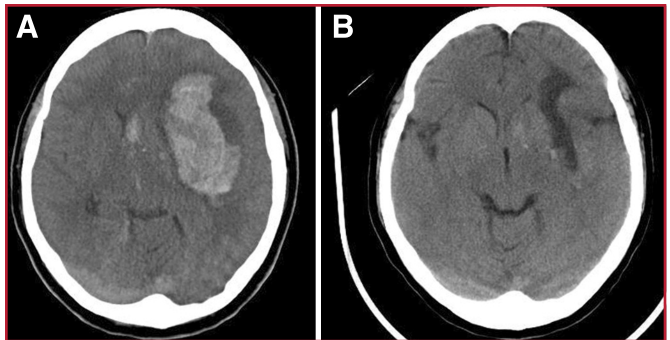

FIGURE 11. **A**, *preoperative CT scan showing a left putaminal hemorrhage in a patient affected by moyamoya disease. This woman, presenting at admission with a Glasgow Coma Scale score of 14, suddenly became comatose and anisocoric during angiography and was operated on after emergency intubation.* **B**, *postoperative CT scan confirms complete hematoma removal.*

Endoscopic Coagulation of Hyperplastic Choroid Plexus

(see video at web site)

Patient Selection

Bilateral choroid plexus hyperplasia is a rare congenital condition that is clinically characterized by early onset of severe communicating hydrocephalus and poor neurodevelopmental prognosis (40, 78). The management of the hydrocephalus in these patients is still a matter of debate. Extrathecal shunting procedures are conditioned by the high CSF production rate (78), and both ventriculoperitoneal shunts (40, 78) and ventriculoatrial shunts (40) are burdened by very high failure rates. Even temporary external ventricular drainage exposes the patient to the risks of cardiovascular and electrolytic disturbances (78). Primary open surgical excision is associated with a high intraoperative bleeding risk with a significant mortality rate and demands a double surgical procedure (40). Endoscopic coagulation of the hyperplastic choroid plexi (70), by itself, only occasionally leads to sufficient control of the CSF production rate (10, 58), but it can help to reduce the bleeding at the time of the craniotomic choroid plexus excision that can be planned as a one-stage procedure with a reduced operative transfusion rate (78).

Endoscopic Technique

A rigid 30-degree Decq (Karl Storz Co.) endoscope with a 3.5 × 4.7-mm introducer was used. All of the surgical proce-

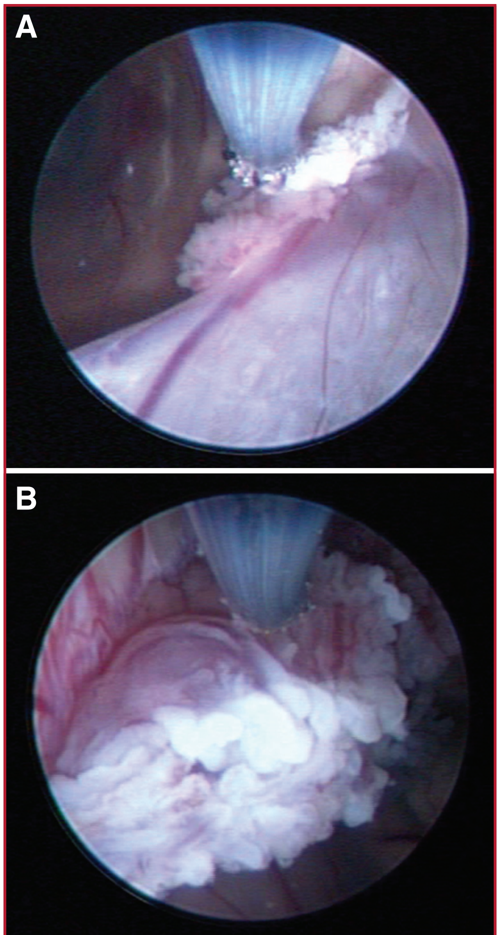

FIGURE 12. **A**, *cauterization of choroid plexus near the right foramen of Monro.* **B**, *cauterization of the choroid plexus and superior choroidal vein in the atrium of the right lateral ventricle.*

dures were performed with a freehand technique and were overlapping for the two sides.

The approach to the lateral ventricles was through a parietal burr hole. After the access to the cella media, the hyperplastic choroid plexi were clearly viewed from the foramen of Monro up to the boundary between the cella media and the temporal horn. A monopolar cautering electrode was used to progressively coagulate, under continuous Ringer's solution irrigation, the surface of the choroid plexi along their entire course in the main chamber of the lateral ventricles, as was performed inside the temporal horns. The cauterization was extended deeply between the different bundles of the choroid plexi to cover the maximum area under view. The whitening of the different portions subsequently faced was considered the signal for a satisfactory reduction of the focal choroid plexus vascularization. No significant bleeding occurred intraoperatively. The total length of the procedure was 65 minutes for the right side and 71 minutes for the left side.

Lesions of the Foramen of Monro: Colloid Cysts

(see video at web site)

Patient Selection

There is a consensus to recommend treatment of all colloid cysts that become symptomatic (55). The advent of the microscope allowed less invasive surgical transcortical–transventricular or transcallosal approaches (5, 44), and microsurgical removal has remained the gold standard for the optimal management of colloid cysts. Nevertheless, the localization of colloid cysts at the level of the foramen of Monro, in dilated ventricles, makes them suitable for an endoscopic approach, which is in fact a minimal percutaneous transcortical transventricular approach with an endoscope. An alternative, palliative strategy such as shunting could only be offered to some elderly patients with nongrowing, calcified cysts.

Endoscopic Technique

All procedures are performed under endotracheal general anesthesia. A 4-cm linear skin incision is made parallel to the midline (or perpendicular to the midline, depending on the hair implantation), 4 cm laterally and 4 cm in front of the coronal suture. A 1-cm-diameter burr hole is performed in a routine fashion. The dura is incised, and the endoscope is introduced into the lateral ventricle. The endoscope we use is a rigid endoscope with an oval sheath (5.2 × 3.5- or 4 × 7-mm outer diameter) that allows the introduction of a 2.9-mm outer diameter, 30-degree telescope and one or two instruments in the remaining space (Karl Storz Co.). Irrigation can also be performed in the same space. Stereotactic or neuronavigation guidance is suitable for patients with normal ventricles. The 30-degree telescope is backward-oriented to allow observation of the foramen of Monro and its posterior part. The colloid cyst is identified, filling the foramen and sometimes partially covered by the choroid plexus. The cyst wall is coagulated and then opened and aspirated using a puncture needle with a transparent cannula that allows visualization of the aspirated content. The colloid material is often very viscous, and initial aspiration is often unsuccessful. With microscissors, the cyst wall is opened as much as possible, facilitating aspiration of the colloid material with an aspirating probe. With a grasping forceps, the capsule is grasped and gently pulled into the lumen of the lateral ventricle. The cyst wall is cut as close as possible to insertion. Then, the residual cyst insertion is coagulated on the choroid plexus situated on the posterior wall of the foramen of Monro. In some cases, there are firm adhesions of the cyst wall on the lateral wall of the third ventricle, and it is not possible to safely remove the cyst from it without any damage. In such cases, all of the visible parts of the remaining capsule are coagulated on its outer and inner sides and left in place. In some particular cases, a posterior puncture of the cyst was required through the most prominent and transparent distended part of the septum behind the foramen of Monro, avoiding the fornix region. It helps to decompress the third ventricle, which often makes the foramen more reachable. Septum pellucidum fenestration is rarely required. Third ventriculostomy may be easily performed when required (in some patients with posteriorly implanted cysts and with enough dilation of the anterior part of the third ventricle). Intermittent irrigation with saline solution is performed when necessary to maintain the quality of vision. The endoscope is then withdrawn. A small piece of Surgicel (Ethicon, Inc., Somerville, NJ) is placed into the cortical chimney. Bone powder is carefully replaced in the burr hole, and the wound is closed in a routine fashion.

In our experience with 49 patients undergoing endoscopic surgery for a colloid cyst of the third ventricle, we were able to achieve total removal in 18 patients (39%) and nearly total removal in 3 patients (6%), whereas remnants of the cyst were still visible on postoperative MRI in 25 patients (54%). In this last group, two patients required a repeat endoscopy; of the two patients, one required a third endoscopy.

There was one case of bacterial meningitis that was successfully treated with antibiotics, five cases of "aseptic" meningitis, and one wound infection. The result of this series and other similar series in the literature illustrate that it is possible to safely remove a colloid cyst with an endoscope in approximately half of the patients, as demonstrated with a cyst-free postoperative MRI, and with a very low morbidity rate. In case of recurrence, the procedure could be safely repeated. Technical improvements are still necessary to improve the quality of a safe removal.

Lesions of the Third Ventricle: Suprasellar Arachnoid Cysts

(see video at web site)

Patient Selection

Endoscopic management of suprasellar arachnoid cysts is considered almost unanimously to be the treatment of choice (11, 12, 15, 20, 23, 43, 82). Results of early experiences had been very encouraging, with a nearly 100% success rate (no further cyst-related treatments) reported by Caemaert et al. (12), Kirollos et al. (43), and Decq et al. (23) when both the apical and basal cyst walls were fenestrated. This is because symptomatic suprasellar cysts are almost universally associated with hydrocephalus, which offers the possibility to work in a large space and to achieve large fenestration (10–15 mm) with subsequent reduction of the risk of reclosure.

Surgery is unanimously indicated in patients with increasing intracranial pressure, visual disturbances, or evolving cysts as indicated on neuroimaging. Endocrine disturbances in an otherwise asymptomatic patient do not appear to be an indication for surgery, because they do not revert after treatment (20). Debate still continues on whether large but asymptomatic cysts require surgery. The position of most authors (20, 82), which we also support, is that a conservative approach should be chosen despite cyst size if a child has no symptoms, is neurologically intact, and undergoes close clinical and radiological observation.

Endoscopic Technique

The entry site is selected to allow a trajectory that permits fenestration of both the apical and basal cyst membranes with minimal anterior-posterior manipulation. As determined on preoperative sagittal MRI scanning, it is usually centered on the coronal suture, approximately 2 cm from the midline. After a burr hole is created and the dura is incised, the endoscope is inserted perpendicularly to the cranial surface. The endoscope is advanced to the foramen of Monro, where the bluish-colored apical dome of the arachnoid cyst becomes visible. An avascular part of the membrane is selected and perforated with the aid of monopolar coagulation. The fenestration is then enlarged with microforceps and inflation of a balloon catheter, thus allowing large communication between the lateral ventricle and the cyst (ventriculocystostomy). The endoscope is then advanced into the cyst, thereby allowing visual inspection of the displaced cisternal contents through the translucent basal cyst wall, and in particular, the tip of the basilar artery and the origin of the third cranial nerves from the brainstem. Multiple fenestrations are made in the avascular portions of the membrane with a blunt probe and a balloon, avoiding the use of any energy source, working in the space between the third cranial nerves and basilar artery from both sides. This creates communication between the cyst and the subarachnoid space of the interpeduncular cistern (cyst-cisternostomy). The endoscope is then withdrawn after adequate hemostasis is visually confirmed.

Ventriculocyst–cisternostomy should be referred to simply as ventriculocistostomy (20, 23, 82), because chronic midbrain, compression may cause an aqueductal occlusion that does not resolve after drainage of the cyst (82). In these cases, the basal stoma allows CSF to flow into the basal cisterns bypassing the aqueduct (*Fig. 13*).

Hypothalamic Hamartomas

(see video at web site)

Patient Selection

Hypothalamic hamartomas are congenital lesions that are associated with intractable epilepsy, precocious puberty, or both. Epilepsy often begins in early infancy with gelastic or laughing seizures. Later in life, these patients have multiple seizure types, violent outbursts, personality disorders, and cognitive problems, especially memory difficulties. All of these problems tend to intensify with the patient's increasing age. Recent experiences with resections of these lesions indicate that removal or disconnection can lead to cure (60%) or amelioration (90%) of the seizure disorder in intractable cases (37a, 58a). In some ways, these lesions are ideal candidates for endoscopic resection in that they are focal and have a visible interface with the wall of the third ventricle (*Fig. 1*). Actually, there are significant challenges. There is no hydrocephalus, and therefore, the ventricles are normal in size. Usually, the foramen of Monro is obscured by the choroid plexus, which must be moved aside to enter the third ventricle (*Fig. 2*). The interface with the wall of the ventricle is distinct, but there are no visual clues as to where the hamartoma ends and the normal hypothalamus begins. This interface must be defined using frameless stereotaxis.

Not all patients with hypothalamic hamartomas are candidates for endoscopic resection. The ideal candidate is one with

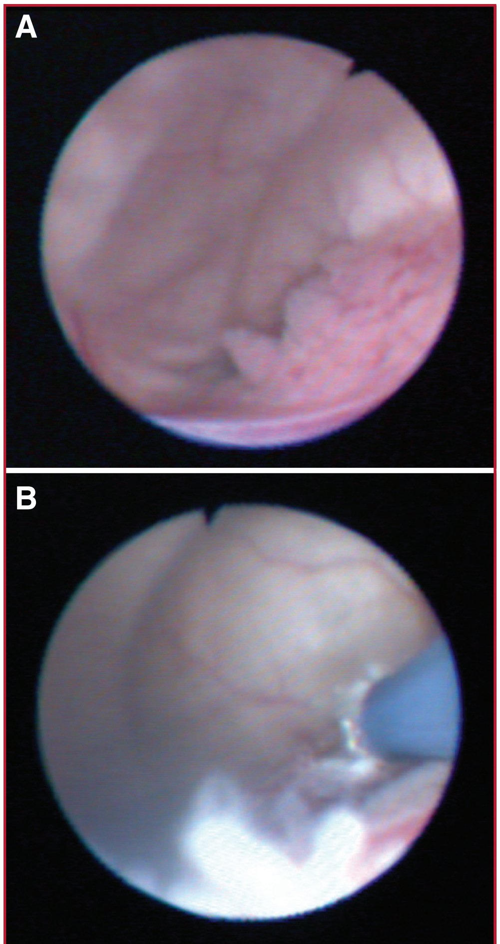

FIGURE 13. **A** *and* **B**, *cauterization of the choroid plexus in the temporal horn.*

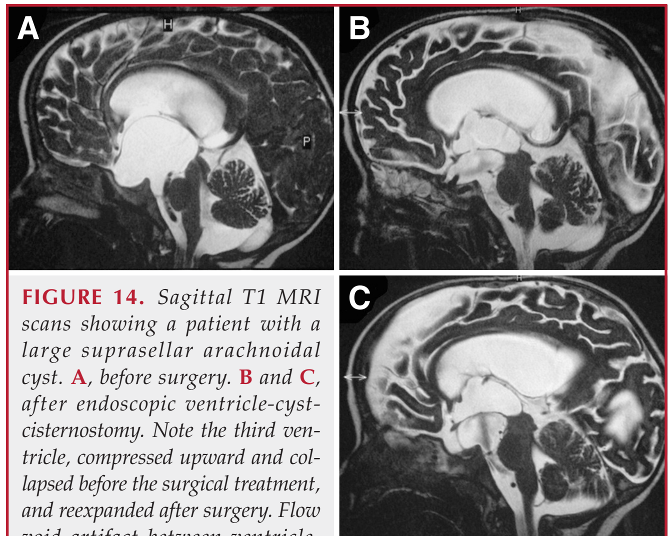

FIGURE 14. *Sagittal T1 MRI scans showing a patient with a large suprasellar arachnoidal cyst.* **A**, *before surgery.* **B** *and* **C**, *after endoscopic ventricle-cyst-cisternostomy. Note the third ventricle, compressed upward and collapsed before the surgical treatment, and reexpanded after surgery. Flow void artifact between ventricle-cystostomy and cyst-cisternostomy is easily visible within the cyst (***C***).*

a small lesion completely on one wall of the hypothalamus and a space between the bottom of the hamartoma and the pial surface of the interpeduncular cistern. It is essential that there is a working distance between the roof of the third ventricle and the top of the hamartoma. In general, this distance must be at least 6 mm to remove the mass under direct vision.

Endoscopic Technique

High-resolution volumetric images are obtained before the procedure (*Fig. 14*) for the use of frameless stereotaxis (Stealth System; Medtronic Corp., Minneapolis, MN). The patient's head is placed in three-point fixation either in a standard Mayfield apparatus or in a gel headholder specifically designed for the fixation of an infant's head without the need for pins. The head is placed in a face-up position with the head slightly flexed. After registration, the entry point for insertion of the neuroendoscope is chosen contralateral to the point of interface with the wall of the hypothalamus allowing an approach to the foramen of Monro that does not require traction on the column of the fornix to permit reaching the anterior margin of the lesion. The entry into the lateral ventricle is often one of the most challenging and critical maneuvers in the performance of the endoscopic resection.

A standard burr hole is drilled that is at least 1 cm in diameter to allow the unfettered insertion of a 20-French (7 mm) peel-away sheath under neuronavigational guidance. Once the ventricle is cannulated, the peel-away sheath is affixed to the skin.

We have used the Minop System (Aesculap, Inc.) with an endoscope that has a 30-degree lens. A metal sheath is used over the insertion trocar and a three-point Sure Trac (Medtronic Corp.). The tip of the scope then becomes a pointer for the Stealth System, and the tip of the endoscope is able to be tracked by the SureTrac. We used the mechanical arm to hold the endoscope (Unitrac; Aesculap, Inc.) for gross movements and a micromanipulator (Neuropilot; Aesculap, Inc.). It should be noted that there is an intact ependymal lining overlying the hamartoma, and there is no difference in color between the normal and abnormal tissue. Using the pituitary rongeurs through the endoscope, the resection begins along the line of interface. Using the guidance system, the hamartoma is fully disconnected from that wall. After the deep margin of the hamartoma is defined, the resection is continued medially toward the free wall of the hamartoma, and an attempt is made to remove the mass in its entirety. Likewise, an attempt is made to maintain the integrity of the pial surface at the level of the interpeduncular cistern if at all possible, but in the case of large hamartomas, which may extend well down to the level of the clivus, this may not be feasible.

The fact that there are no visual clues to go by except trajectory during the resection itself is a limitation. For very large hamartomas (larger than 1 cc in volume, approximately 1.5 cm in maximum diameter), the process of the resection progress leads to some distortion of the floor of the third ventricle and loss of the trajectory landmarks. We then use an intraoperative

3-T MRI scanner and hope to extend the likelihood of successful resection to larger lesions.

A possible complication is hemiparesis resulting from damage to the internal capsule attributable to an error in the insertion trajectory. Some patients present with small areas of infarction observed in the thalamus on the same side as the lesion which occurs when the pial surface was breached with minor bleeding and possible transient contralateral hemiparesis. Temporary increased difficulties in short-term memory can be occasionally observed. Neuropsychological assessment reveals improvement in cognitive skills, speed of processing, and memory in the majority of patients.

Chiasmatic Gliomas

(see video at web site)

Patient Selection

Chiasmatic gliomas are a subject of controversy because of their low incidence in the general population, their highly variable growth rate, and the variety of treatment plans proposed by different groups (66). The therapeutic strategy ranges from a "wait-and-see" policy to biopsy, partial debulking, radical surgical excision, radiotherapy, and chemotherapy. When surgical therapy is indicated, it should be targeted to: 1) achieve a correct histological diagnosis; 2) eliminate mass effect; and 3) preserve or restore visual and/or neuroendocrinological function. Chiasmatic gliomas may grow inside the third ventricle, can be associated with hydrocephalus, and can present as cystic components or adjacent arachnoid cysts (45). The mass effect on surrounding brain and CSF pathways may be caused by the cystic component; thereafter, decompression of the cyst may lead to resolution of hydrocephalus and, in some patients, long-term control of symptoms and signs as a result of the indolent nature of chiasmatic tumors, especially in children (57).

Endoscopic Technique: Endonasal Approach

(see video at web site)

Besides the traditional transcranial approaches, which have been used for the biopsy and excision of the lesions, the microsurgical transsphenoidal approach has been used on selected patients to obtain tumor samples. Nevertheless, during the past decade, the increasing use of transsphenoidal endoscopy has gradually enlarged the horizons of conventional transsphenoidal surgery in that not only limited to the sellar region, but extended to all of the parasellar areas from the clivus to the cavernous sinus and above all of the planum sphenoidale. More recently, neurosurgeons have been focusing their interest on the transsphenoidal transplanum approach to the suprasellar area as a result of the possibility of exposing the suprasellar neurovascular structures and, among them, the optic pathways. This approach is currently used in different centers around the world either with an endoscopic or endoscope-assisted technique for the removal of purely suprasellar lesions such as tuberculum sellae meningiomas, craniopharyngiomas, and Rathke's cleft cysts (19, 22, 26, 42, 48).

Thanks to its wide and close-up view of the optic pathways and particularly of its inferior surface, this extended transplanum route can be used not only for the biopsy of chiasmatic gliomas, but also to remove, when indicated, the lesion itself. Not all of the chiasmatic gliomas can be approached through the extended transsphenoidal route, and the adequate preoperative evaluation of the different relationships of the tumor extension with the optic pathways and the vessels plays a relevant role in the decision-making process for the correct approach.

Although most authors have reported good results with the transcranial treatment of chiasmatic gliomas, the extended endoscopic transsphenoidal approach appears to provide direct, minimally invasive access to these lesions. It allows performance of not only a biopsy, but it also permits a certain degree of lesion removal, thus reducing the mass effect, to preserve or even recover the visual and/or neuroendocrinological functions, which themselves represent the main goals of the surgical treatment for these lesions.

Endoscopic Technique: Transventricular Approach

(see video at web site)

In patients who present with a significant cystic component (*Fig. 15, A–C*) and large ventricles, transventricular endoscopy has some advantages over other drainage techniques (25, 59). The burr hole is usually precoronal, because the tumor usually grows into the third ventricle and the cystic component bulges into the lateral ventricles, obstructing the two foramen of Monro and inducing noncommunicating biventricular hydrocephalus. The capsule is usually observed bulging through the foramen as a yellowish translucid membrane. With a monopolar coagulator, it is possible to perforate the capsule under visual control. After perforation, it is preferable to introduce a catheter into the cyst before enlarging the stoma to remove all of the cystic fluid and to avoid blurring of the endoscopic vision with the yellowish fluid contaminating the ventricle. After this aspiration, it is possible to enlarge the opening, thereby obtaining a radical cyst drainage and access to the lateral ventricle. Partial resection of the capsule and sampling of tissue fragments under direct vision can usually be performed without major difficulties as well as fenestration of intercavitary septations in case of multiloculated cysts or wide marsupialization into CSF fluid.

In case of obstruction of the single foramen of Monro, with asymmetrical hydrocephalus, endoscopic septostomy may be performed alone with the aim of bypassing the blocked foramen, thereby restoring the passage of CSF to the contralateral ventricle. In case of bilateral obstruction and a major solid component filling the third ventricle, septostomy should be associated with ventriculoperitoneal shunting to restore CSF pathways. Single endoscopic drainage of the tumoral cyst does not usually produce a sustained effect, because the cysts tend invariably to re-accumulate (74). Fenestration of the cyst and inspection of it with an endoscope allow continuous dilution of the cyst's fluid and resorption through the CSF pathways.

CRANIOPHARYNGIOMAS

Transnasal Approach

(see video at web site)

Patient Selection

Although craniopharyngiomas have benign histological characteristics, their deep location, their proximity to important neurovascular structures, their different relationships with the brain and with the pial and subarachnoid space, and their tendency to recur make these tumors one of the most challenging lesions in neurosurgery. The goal of the surgical treatment is radical removal, and the transcranial approaches are still considered the approaches of choice for the suprasellar and intraventricular tumors.

Besides the well-established microsurgical transsphenoidal technique described in 1987 by Weiss (85), in the past decade, endoscopic transsphenoidal surgery has progressively diffused throughout neurosurgery thanks to its wider and multiangled view. This has allowed us to perform surgical excision of suprasellar tumors as well, including craniopharyngiomas, using a pure, fully endoscopic extended transsphenoidal approach (22).

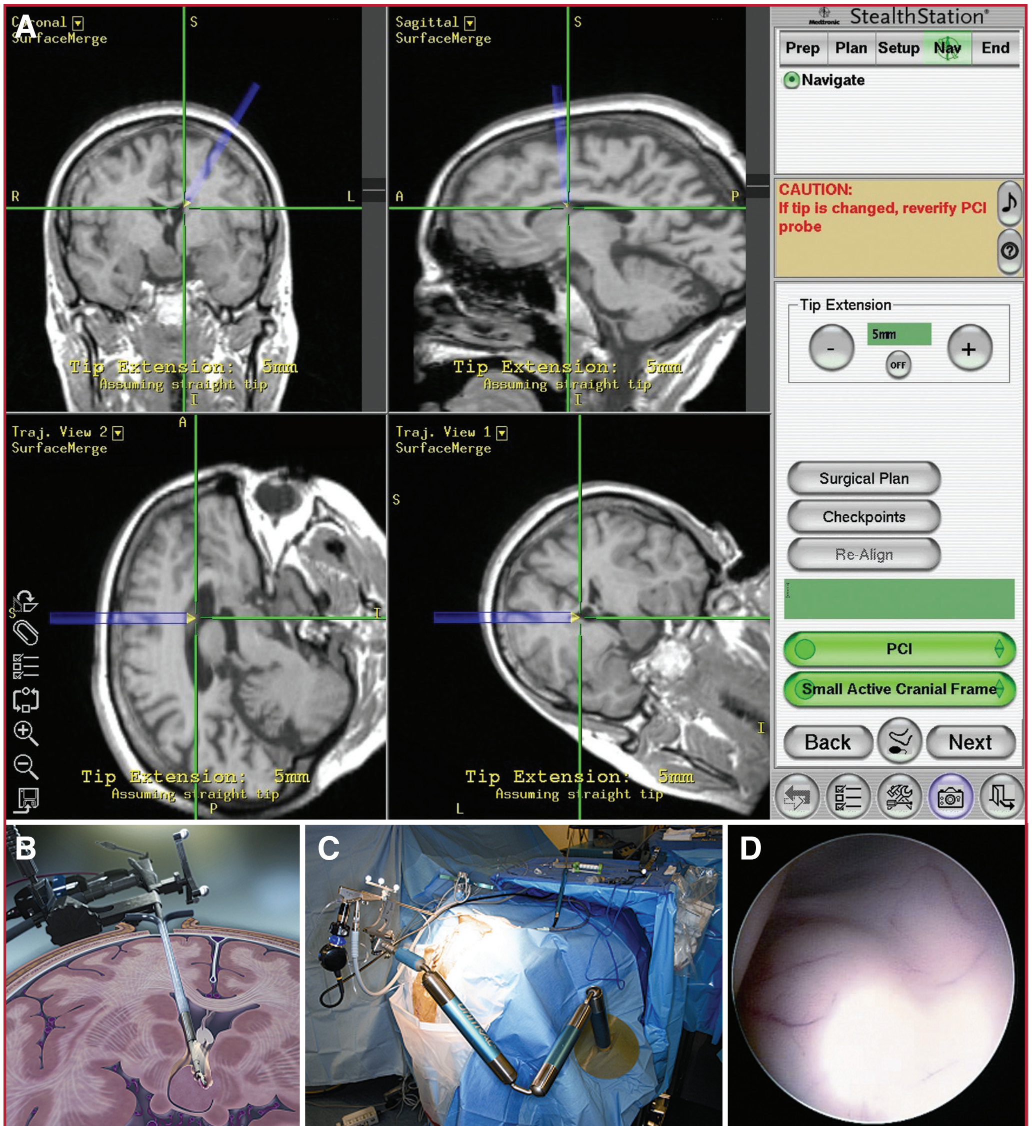

FIGURE 15. A, *preoperative planning for an endoscopic approach to the hypothalamic hamartoma.* B, *schematic image showing the trajectory of the endoscope.* C, *intraoperative image showing the endoscope fixed to the autostatic arm.* D, *intraoperative endoscopic image showing a hypothalamic hamartoma.*

Endoscopic Technique

The extended transsphenoidal approach to the suprasellar area, using either a microscopic or endoscopic technique, requires additional bone removal above the sella, including the tuberculum sellae and the posterior portion of the sphenoid planum, extended bilaterally in the direction of the opticocarotid recesses, and is performed through two-nostril access. The extended transsphenoidal route allows access from below the various types of craniopharyngiomas so that dissection can be performed under direct visual control. Using the same surgical corridor, the surgeon, depending on the site of the lesion, can work either below or above the optic chiasm and through both sides of the stalk, thereby allowing the management of both the suprasellar prechiasmatic and the intraventricular craniopharyngioma. This approach, which does not require brain retraction, permits early exposure of the lesion and good visualization of the pituitary gland and stalk and the main vascular structures and minimizes optic apparatus manipulation. Despite encouraging preliminary reports on series of patients operated on with this technique, there are still some problems and limitations to be considered: 1) size of the tumor, 2) depth of the operative field, 3) management of hemorrhage, 4) osteodural defect reconstruction, and 5) adequate instrumentation.

Keyhole Approach

(see video at web site)

Patient Selection

Most craniopharyngiomas arise from the suprasellar or intrasellar compartments and extend superiorly into the third ventricle. They may elevate or penetrate the floor, a distinction that cannot be made with preoperative imaging. These lesions are best removed using a subfrontal or pterional approach. The subfrontal approach is limited if the optic chiasm is prefixed, which forces the surgeon to either go through the lamina terminalis or the opticocarotid window. Similarly, the pterional approach is limited if the tumor has significant suprasellar extension, but it is the preferred approach when the tumor has bilateral parasellar components. With very large tumors, both approaches are inadequate alone. This is when the endoscope can play a vital role in the complete macroscopic removal of these difficult tumors. The scope has the advantage of taking light to the target, enabling the surgeon to see around corners, increasing the magnification, and clarifying the tumor–brain interface. A 30-degree endoscope placed into the tumor bed and pointing superiorly will help the surgeon explore and access the third ventricle. Rotated the other way, the endoscope gives the surgeon a view of the sellar contents.

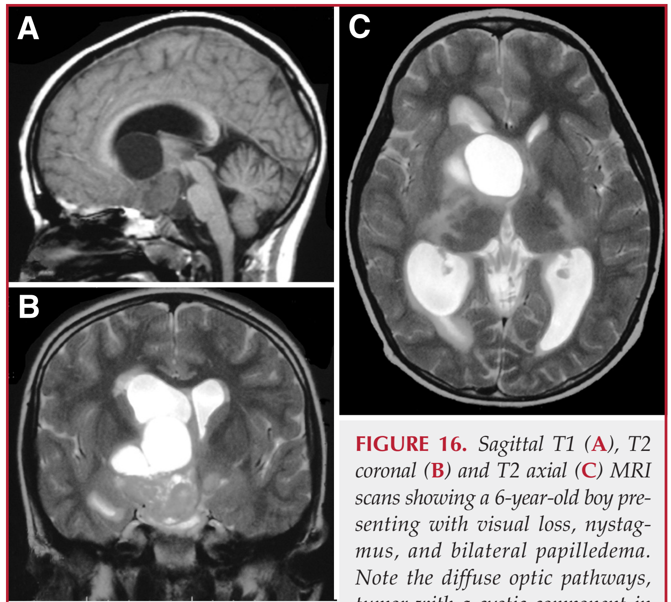

FIGURE 16. *Sagittal T1 (**A**), T2 coronal (**B**) and T2 axial (**C**) MRI scans showing a 6-year-old boy presenting with visual loss, nystagmus, and bilateral papilledema. Note the diffuse optic pathways, tumor with a cystic component in the frontal horn of the right lateral ventricles, and hydrocephalus (*Video 17*).*

Endoscopic Technique: The Subfrontal Approach through an Eyebrow Incision

The most frequent use of the endoscope is as an adjunct to standard microsurgical approaches. This is known as endoscope-assisted surgery. The generous view offered by the endoscope allows one to significantly limit the size of the craniotomy even if there is marked suprasellar, retrosellar, or intrasellar extension. This approach has been given many names (transciliary, supraorbital, eyebrow, subfrontal, orbital roof, and so on) and has many variations. The incision can be made either through the eyebrow or above it (*Fig. 16*), the orbital rim can be taken or preserved, and the sylvian fissure can be split or left alone. We recommend an incision through the eyebrow itself, preserving the supraorbital nerve, and the pericranium. If necessary, the incision can be continued laterally into the non-hair-bearing area, but this significantly increases the risk of permanent damage to the frontal branches of the facial nerve. The pericranium is then elevated anteriorly as a separate flap of tissue (*Fig. 17*), which later provides some barrier to CSF leak or a means of covering a breached frontal sinus. A burr hole is then made in the "keyhole" area and a small craniotomy is fashioned, and attempts are made to leave the frontal sinus intact. The orbital rim can be removed if there is excessive suprasellar extension of the tumor, but in most cases, this is unnecessary. The orbital roof protuberances are then flattened with extradural drilling before the dura is opened. CSF egress is encouraged by wide opening of the cisterns and the lamina terminalis. The tumor is removed in piecemeal fashion. Care is taken not to exert too much traction on the walls of the third ventricle. Another important surgical dictum is to preserve all perforating vessels that are coursing around the tumor. This includes those small vessels that supply the optic nerves and chiasm. We use the endoscope to identify important surrounding neurovascular structures once the tumor has been decompressed by cyst drainage. It is imperative to do this "exploration" earlier in the operation rather than later. The thinly stretched pituitary stalk is sometimes visible with the angled endoscope. The suprasellar portion can be removed by splitting the fissure and using a 30-degree endoscope for visualization. In many circumstances, the intraventricular portion requires an approach through the lamina terminalis. Removal of the intrasellar portion can be augmented with the 30-degree endoscope rotated the other way, aimed inferiorly into the often capacious sella. The superior view afforded by the 30-degree scope has revealed, on several occasions, tumor carpeting the parasellar portion of the internal carotid arteries, the undersurface of the optic apparatus, the interpeduncular fossa, and the pituitary stalk.

Endoscopic Technique: The Minipterional Approach

The incision is made just behind the hairline of the temporal area in a gentle curve, making sure that the anterior limb of the incision does not cross the hairline or approach too close to the frontalis branches of the facial nerve (*Fig. 18*). The muscle is split in the longitudinal plane and a small craniotomy is opened, centered on the pterion. This is a more lateral approach that allows excellent dissection through the opticocarotid window. The endoscope can be placed through this craniotomy and used to view superiorly and inferiorly, similar to the subfrontal approach. Care must be taken when placing the scope into the operative field, because vessels and brain may be inadvertently damaged. We recommend

FIGURE 17. *Skin incision showing a subfrontal approach through the eyebrow.*

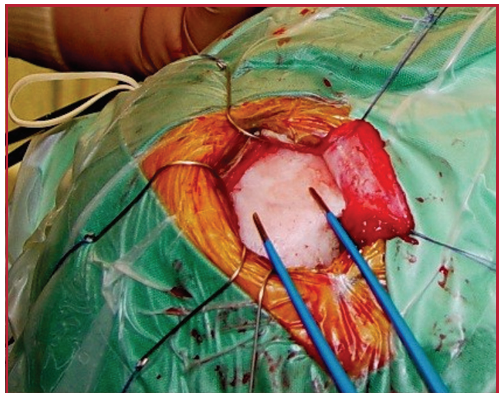

FIGURE 18. *Periosteal flap is demonstrated.*

placing the scope into the tumor bed under microscopic visualization. Once in a good position, the microscope can be removed, and the surgeon can turn his or her eyes to the monitor. Endoscope holders are not sophisticated enough to replace a good assistant.

Endoscopic Transventricular Approach for Marsupialization

(see video at web site)

Patient Selection

A predominantly cystic lesion can be observed in 60% of craniopharyngiomas (77). When mass effect rather than infiltration is responsible for symptoms, cyst drainage is an acceptable compromise for most patients, especially in recurrences and for elderly patients. In the last decade, neuroendoscopy has been increasingly used and has shown great versatility both as a sole procedure and as a step in a multimodal protocol (16).

Cysts impinging on or growing into the ventricular system (Yaşargil's C to F types) (86) are suitable for an endoscopic approach. Different techniques have been proposed for a wide range of therapeutic effects ranging from gross total removal (2) to control of hydrocephalus before microsurgery (16). In our experience (25), cystoventiculocisternostomy (i.e., wide marsupialization of the cyst in the ventricles and basal cisterns) is the procedure of choice, because it has been proven to be safe, effective, and easily repeatable in the long-term control of tumor.

Endoscopic Technique

This procedure, conceptually based on the classic stereotactic work of Spaziante et al. (77), is performed in four basic steps: 1) standard precoronal parasagittal approach to the lateral ventricle; 2) identification and puncture of the cyst's dome and complete drainage of its content by washing with Ringer's solution; 3) coagulation and resection as extensive as possible of the cyst's dome, cavity exploration, and biopsy; and 4) perforation of the cyst's fundus into basal cisterns. We also emphasized the "stenting" of the cyst (i.e., transcystic positioning of a multiholed catheter) as an effective measure to ensure CSF circulation and prevent refilling, even in the case of reclosure of the marsupialized cavity. Steps 3 and 4 should be carried out only after clear identification of proper anatomic landmarks, limiting the procedure to cyst drainage in case of excessive anatomic distortion. The neuroendoscopic approach to cystic craniopharyngiomas allows control of mass effect, preservation of function, and integration with other therapeutic means (microsurgery, radiation therapy, radiosurgery). In our series (25), complete drainage was achieved for all but one patient as a result of an inaccessible pouch separated from the main cavity. There were no intraoperative complications and no chemical meningitis was observed. One case of recurrence and one enlarging, previously undrained pouch were successfully endoscopically reevaluated.

Additional experiences and longer follow-up are needed to address two main issues: recurrence rate and possible CSF seeding. The neuroendoscopic approach represents a major advance compared with classic draining techniques, because emptying is performed under direct vision, which allows partial resection of the capsule for diagnostic purposes and wide marsupialization. Perforation into basal cisterns and stenting are measures to prevent reclosure and recurrence. If indicated, other therapeutic modalities (microsurgery, radiosurgery, fractionated external radiation therapy) can be scheduled later to eradicate solid remnants.

Endoscopic Transventricular Approach for Complete Removal

(see video at web site)

Patient Selection

Only a minority of small, completely intraventricular, noncalcified craniopharyngiomas are amenable to endoscopic resection. Often, the solid portions arise outside the third ventricle, usually in the suprasellar cistern, and present an intimate relationship with the hypothalamus, optic pathway, major vessels, and perforating vessels of the cranial base; they cannot be removed without the risk of uncontrollable damage to these neurovascular structures. The solid remnants, in these cases, should later be considered for microsurgery or radiation therapy (25, 59, 81).

Only Abdullah and Caemaert (2) achieved, with endoscopic techniques, gross total removal of a predominantly cystic craniopharyngioma of the third ventricle. However, two endoscopic operations were required. In the postoperative period, the patient developed behavioral disturbances, severe electrolyte imbalance and hydrocephalus, and the patient had permanent sequelae after surgery. In a second patient, only partial removal was achieved, but the patient remained in a prolonged somnolent condition after endoscopy and died 2 months later.

Illustrative Case

Our experience with gross total removal of intraventricular craniopharyngioma is limited to one patient that has already been the object of a report (16). The patient was a 3-year-old girl with a 1-month history of headache and vomiting. Clinical examination showed bilateral papilledema. Neuroradiological investigation revealed a cystic tumor with a diameter of 2.5 cm and peripheral calcification into the third ventricle, associated with mild hydrocephalus. The patient was operated on under general anesthesia using a rigid fiberscope (Channel Neuroendoscope; Medtronic). A right precoronal burr hole was drilled 3 cm away from the midline, the fiberscope was inserted in the ventricular system, and the craniopharyngioma was identified in the third ventricle. The capsule was widely opened with monopolar coagulation (ME2; Codman & Shurtleff, Johnson & Johnson, Raynham, MA), microscissors, and forceps. The cystic content was aspirated, and the capsule and the solid contents were removed piecemeal with the help of both monopolar and bipolar coagulation, microscissors, and grasping forceps. The lesion was purely intraventricular and was easily dissected from the floor of the third ventricle. Only a portion of the capsule strictly adhered to the anterior fornix, but it was grasped without excessive traction on the surrounding structures. Histological examination revealed an adamantinomatous craniopharyngioma. The postoperative course of the patient was uneventful, except for occurrence of diabetes insipidus. Postoperative imaging confirmed the gross total removal of the tumor and resolution of the hydrocephalus. At 3 years follow-up, no clinical or radiological recurrence was observed.

Lesions of the Pineal Region: Role of Endoscopy in the Algorithm of Treatment of Pineal Tumors

(see video at web site)

Patient Selection

More than 17 different tumor pathologies exist in the area of the pineal region alone. The major purpose of applying the neuroendoscope as the initial procedure in pineal tumor management is to identify the pathological characteristics of the tumor because of the high possibility of chemo- or radiosensitivity in the majority of these cases. If the tumor markers (alpha-fetoprotein, human chorionic gonadotropin) are negative in serum, and even when ventriculomegaly is not identified on CT or MRI scans, neuroendoscopic surgery is first applied for tumor debulking and tissue diagnosis with gross morphological analyses of the tumor and the intraventricular/intracisternal structures. Information on the gross appearance of the tumor and the presence of tumor dissemination is therefore obtained. Endoscopic third ventriculostomy is performed in the standard fashion if necessary. Neuroendoscopic surgery is performed as the initial procedure even on patients with small ventricles. If tumor markers are positive, extensive surgery is first attempted for radical total removal, unless there is no endoscopic evidence of tumor dissemination. In patients with tumor dissemination in this group, immediate neoadjuvant chemotherapy as the initial procedure is started, followed by whole neuro-axis radiation therapy. If the CSF cytology is positive postoperatively, the external ventricular drainage is continued for as long as possible, along with chemotherapy, in all patients treated with any surgical procedure.

Surgical Instruments

The body of the rigid endoscope comprises an oval-shaped outer sheath (3.5 $\times$ 2.5-mm maximum diameter and 16.5-mm long), a rigid-rod objective lens (2.0-mm diameter with a 0- or 12-degree angle), a working channel (upper one-third of the sheath connected to three-outlet/inlet orifices), and a handle attachment knob to which a holding handle can be affixed (Oi Handy Pro; Karl Storz Co.). The three-outlet/inlet orifices are used for irrigation (left), suction (center), and microinstrumentation (right). Irrigation and suction procedures are undertaken by opening either the left or center orifice, respectively (*Fig. 19*).

Endoscopic Technique

Through a burr hole that is 8 mm in diameter, a 14-French transparent peel-away catheter (63) is passed into the target ventricle. The endoscope is inserted into the ventricle through the peel-away catheter, and anatomic landmarks are identified. Steady holding of the endoscope in the surgeon's left hand over the handle grip at the base allows quick back-and-forth movements along the long axis through a peel-away sheath inserted into the ventricle with minimally required side shift of the tip of the endoscope to the objective target. Using the rightmost inlet/outlet orifice, the short, semiflexible microinstruments can be guided and controlled by the surgeon's right hand. Irrigation is facilitated by the assistant manually injecting artificial CSF. For balloon techniques, a 2-French Fogarty balloon (1.0-mm diameter and 5-mm maximum inflation) is used. The neuroendoscope, with a biopsy microforceps placed in the working channel, is guided toward the pineal region. The microforceps are advanced and the forceps are opened. Once the tissue is grasped and detached from the body of the tumor, the entire endoscope is removed through the guide sheath together with the microforceps grasping the tissue. The microforceps and accompanying tissue should not be removed through the working channel of the endoscope, because the tissue may be damaged or the tip of the microforceps may become caught at the orifice of the endoscope. Biopsy at several locations is performed first. After irrigation, neuroendoscopic third ventriculostomy is performed, redirecting the neuroendoscope in the peel-away sheath. The advantage of a rigid rod-lens endoscope is the high-resolution imaging, which makes this neuroendoscope superior to the flexible type. The

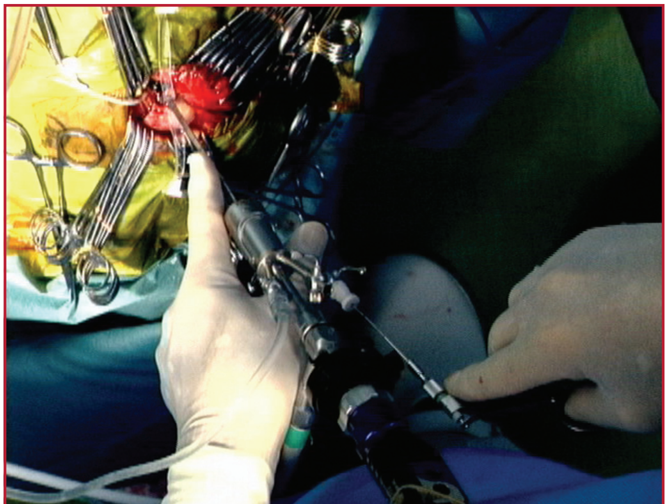

FIGURE 19. *The endoscope is held with the left hand by the handle, and instruments are introduced with the right hand.*

small size of this neuroendoscope enables operation and maneuvering through a normal-sized foramen of Monro with minimal, if any, compression, and allows the posterior fossa to be reached through the dilated third ventricle and aqueduct of Sylvius. We were able to maneuver using a single burr hole to perform tumor biopsy plus ETV or cyst fenestration plus ETV. Use of a single burr hole for more than one task is limited to the flexible neuroendoscope or use of a rigid endoscope with two burr holes (64). Results for patients in our study confirm existing reports regarding the efficacy of this neuroendoscope, with 100% tissue diagnosis, 87.5% control of pathology, and no direct mortality or morbidity related to the procedure.

Management of Pineal Tumors with Steerable Endoscope

(see video at web site)

Patient Selection

The type of endoscope to use must be selected on the basis of the chosen surgical strategy and the radiological images. In general, in cases in which both the foramen of Monro and the third ventricle are enlarged by hydrocephalus and the position of the burr hole is correctly chosen, using a flexible fiberscope or a rigid-lens endoscope may not make any difference, because there will be sufficient space to follow the floor of the third ventricle backward to the tumoral mass or to overcome the massa intermedia without stressing the anterior or posterior margin of the foramen of Monro (32). On the other hand, in cases in which the foramen of Monro and third ventricle are relatively narrow, use of a flexible endoscope will provide the great advantage of "navigating" the ventricles and orienting its tip to seek the tumor either from below or above the massa intermedia. Furthermore, it is our opinion that fiber endoscopes represent an ideal instrument for achieving fine movements while exploring the patient's ventricular cavities, because the weight of the camera is not directly resting on the surgeon's hand, but lies just beside him or her on a holding structure or on the surgical table.

Endoscopic Technique

Burr-hole position is planned on MRI sagittal images. A too-posterior burr hole may provide direct access to the third ventricle floor for ETV but exert too much strain on the structures of the posterior margin of the foramen of Monro (choroid plexus, thalamostriate vein, and septal vein) during the attempt to reach the tumoral mass in the posterior third ventricle. Placing the burr hole too anteriorly could put traction on the fornix when performing the ETV. We suggest placing the burr hole between 2 and 3 cm in front of the coronal suture and, in all cases, to study sagittal MRI scans to plan the trajectory in advance (*Fig. 1*) (31, 71). After cannulation with a peel-away sheath, a CSF sample will be obtained for tumor markers and cytological examination. The endoscope can then be introduced in the lateral ventricle, and a third ventriculostomy can be performed in a standard fashion. The tumoral mass is biopsied following two different pathways: either directing the endoscope posteriorly to follow the floor of the third ventricle until the bulging of the tumoral mass can be visualized in the pineal region or, in cases in which the massa intermedia is large or forbids direct visualization of the tumor, by partially retracting the endoscope while remaining within the third ventricle and surmounting and surpassing in a posterior direction of the massa intermedia until the tumor can be observed below (see video). The surgeon will perform the small forceps biopsy of the mass and control any moderate bleeding via monopolar coagulation. Finally, the endoscope will be removed and the burr hole closed.

Quadrigeminal Cysts

(see video at web site)

Patient Selection

Cysts originating in the quadrigeminal plate cistern are usually suitable for endoscopic treatment, for several reasons. First, the presence of an area of contiguity between the cyst wall and the ventricular ependyma or subarachnoid spaces is the rule in this kind of cyst and can be simply detected on preoperative imaging (*Fig. 20*). Quadrigeminal cysts are almost invariably associated with hydrocephalus secondary to compression or distortion of the aqueduct; this allows the surgeon to work in larger spaces (12, 15, 23, 38) and to perform a "transventricular ventriculocystostomy" approaching the ventricular system, and thus the cyst, first. Finally, the anatomic presentation of these cysts usually allows an additional fenestration apart from the ventriculocystostomy: a third ventriculostomy or cyst–cisternostomy. This additional fenestration should reduce the tendency of the stoma to close, because it creates a direct flow from the ventricular system to the basal cisterns (23). The choice of endoscopic approaches and trajectories is made on the basis of preoperative MRI scans. Cysts expanding cranially in the lateral ventricle through the medial wall of the trigone or laterally in the ambient cistern may be approached from the lateral ventricle through a parietal burr hole; the cysts that expand caudally in the supraretrocerebellar cistern (bulging in the posterior part of the third ventricle), forward in the third ventricle, and those that excavate the tegmen of the midbrain may be approached from the third ventricle using a precoronal trans-Monro approach.

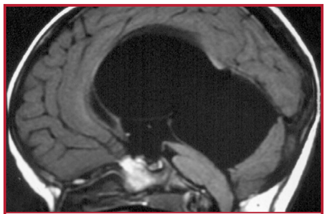

FIGURE 20. *Huge cyst of the quadrigeminal cistern extending in the supratentorial compartment.*

Endoscopic Technique

For cysts bulging in the third ventricle, the lateral ventricle is approached through a right paramedian precoronal burr hole. This should be placed more anteriorly than for a standard ETV if a rigid scope is used. The endoscope is advanced into the foramen of Monro. After the endoscope enters the third ventricle, the cyst wall will come into view, usually protruding through the posterior part of the third ventricle. In some patients, the entire third ventricle is filled by the cyst. The ependyma and the cyst wall are opened by means of monopolar or bipolar coagulation; the fenestration is enlarged by grasp forceps and a 3-French Fogarty balloon or double balloon catheter (Lighttouch balloon; Integra Neuroscience, Biot, France). Wall tissue is removed with the aid of microforceps, enlarging the diameter of the stoma to almost 1 cm. After decompression of the cyst, further fenestration between the third ventricle and the interpeduncular cistern (third ventriculostomy) can be safely performed using the same approach.

For cysts that extend upward in the lateral ventricle, large fenestration through the medial wall of the lateral ventricle is usually feasible. In these cases, the two internal cerebral veins are both displaced on one side, and the ventricle to enter should be chosen on this basis to avoid the risk of harm to these important vascular structures.

For cysts extending laterally in the ambient cistern, this approach is often inadequate. A parietal burr hole, with the patient's head rotated 90 degrees on the contralateral side, is usually indicated to approach the lateral ventricle at the level of the trigone. In these cases, third ventriculostomy cannot be performed by the same approach; thereafter, additional fenestration of the deep wall of the cyst toward the basal cisterns is recommended to prevent reclosure of the stomies. For large cysts without hydrocephalus treated in newborns, closure of the fenestrations occurs frequently, and in these cases, large resections of cyst wall are indicated.

Lesions of the Fourth Ventricle: Indications for Navigation into the Fourth Ventricle

(see video at web site)

Few reports have focused on the endoscopic exploration of the fourth ventricle. Since the 1990s, Matula et al. (56), summarizing their experience on this topic (most of the work was done in their laboratory) stated that there are three possible approaches to reach the fourth ventricle endoscopically: 1) through the cerebellomedullary cistern through the foramen of Magendie, 2) coming from the third ventricle through the aqueductus cerebri, and 3) through the basal cisterns opening of the lateral Luschka.

Most of the clinical experiences concerning the approach through the cerebellomedullary cistern have been practiced through a midline durotomy between the opisthion and the posterior arch of C1, advancing toward the fourth ventricle through the foramen of Magendie (33). This caudal approach has been used both with rigid and flexible scopes either for opening the foramen of Magendie that is obstructed by pathological membranes or aspirating cysts, but particularly for reaching the aqueduct and performing aqueductoplasty.

The second option (through the aqueductus) implies a frontal approach and passage through the aqueduct; until recently, this was considered, like the columns of Hercules, unnavigable. The versatility of flexible scopes can be fully exploited to provide the best target for this goal. The right frontal horn is first cannulated with a 14-French peel-away, and through this access, a flexible endoscope is introduced. During the whole procedure, instrumentation is managed with a freehand technique using movements of advancement, flexion, extension, and rotation. In the third ventricle, the scope is stirred toward the aditus aqueduct and advanced in the ampulla and toward the fourth ventricle. Although tight, the cerebral aqueductal channel is compliant; thus, an instrument 4 mm in diameter can pass through the aqueductal channel. After passing the aqueduct additum, a narrowing corresponding to the superior colliculi is first recognizable; then a more dilated space called the aqueduct's ampulla is encountered, followed by a further restriction in correspondence to the inferior colliculi.

Once the aqueduct is cannulated, irrigation should be stopped, because the instrument itself occupies and closes the aqueduct with its own volume. Additional increments of liquid volume could overload the fourth ventricle, which in this particular phase could become completely trapped (depending on the pathology below). Related episodes of threatening bradycardia could be the clinical consequence. Another observation concerns the vision offered to the neurosurgeon; the posterior deflexion of the scope and posterior stirring cause an overturned upside-down view of the video/endoscope images. The sulcus medianus of the fourth ventricle is the guiding anatomic mark leading toward the posterior triangle of the rhomboid fossa with clear evidence of calamus scriptorius with the caudal trigona of hypoglossus of vagus, area postrema canalis centralis medullaris spinalis ending in the foramen of Magendie (51).

Neuronavigation beyond the aqueduct, however, can be of some interest only in very selected situations. Our preliminary experience began with cases of a trapped fourth ventricle in an infant with posthemorrhagic hydrocephalus. Exploration proved to be difficult because of the enlarged ventricle and poor visualization of the rhomboid fossa; in most of the patients, it was so deformed that it was unrecognizable. Another interesting indication to the fourth ventricle exploration has been the removal of intraventricular clots as the final stage of aspiration for patients with hematocephalus totalis (51). By this endoscopic method, small tumors could also be biopsied and, if intrinsically frail, even aspirated; furthermore, the opening of an obstructed foramen of Magendie has also been recently illustrated. Fourth-ventricle cysts are reported to have been removed through this approach (3). Although many theoretical objections could be raised against the transaqueductal navigation of the fourth ventricle, in light of our experience, this procedure has been relatively easy and harmless (51).

Future technical evolution that are aimed toward dedicated flexible instruments with a delicate coating that are deprived of residual stiffness in order to navigate the ventricle could provide unexpected opportunities.

Trends, Future Directions, and Lines of Development

Technology will certainly expand the possibilities and indications of the application of the neuroendoscope in neurosurgery. The main limitations to a wider use of endoscopic surgery are the volume of the lesion to remove, the bleeding that can cause surgery in a fluid-filled cavity (i.e., lateral ventricles) to be extremely long and hazardous, and the lack of a bimanual ability to dissect. The forceps that can be inserted through the working channel of an endoscope, whatever its diameter, can only allow for a long, tedious, and sometimes dangerous process of piecemeal removal without any previous dissection; these can only be reasonably and safely adopted for the typology of small pedunculated lesions described at the beginning of this paragraph. Miniaturized ultrasonic surgical aspirators designed for neuroendoscopes are not widely available and have a very limited clinical application thus far. Whatever their effectiveness, ultrasonic aspirators would not resolve the problems of bleeding in a fluid environment (that makes vision suboptimal or insufficient even under continuous irrigation) and the lack of the possibility of magnified microdissection. This can only be obtained by taking a step forward and shifting from purely endoscopic surgery through one or two working channels to a so-called endoscope-controlled microsurgery. With this solution, through a small craniotomy, only the optic is inserted into the surgical field (intraparenchymal, intraventricular, or subarachnoid) and secured to a holder, and both hands can be used for microsurgical dissection with standard or dedicated modified microsurgical instruments (14, 28, 37). This technique, although allowing only bidimensional control with lack of field depth and tridimensional view offered by the microscope, allows for a higher magnification, better illumination, and the opportunity to look behind obstacles with 30- or 45-degree optics through smaller access corridors than with the microscope.

Concerning the quality of the images offered by the steerable fiberscopes, the coming years will certainly witness the progression of the so-called videoscopes. These instruments are structurally similar to traditional fiberscopes because the light is brought to the tip through a bundle of optic fibers, but the charge-coupled device camera is miniaturized and placed at the tip of the endoscope. This solution offers a quality of vision comparable to rod-lens systems, at least for standard procedures. Videoscopes are already commercially available in other disciplines, and we should expect rapid replacement of traditional fiber-optic systems as soon as videoscopes become easily available. Nevertheless, videoscopes will continue to carry with them the limitation of the working-channel diameter through which only one small instrument is allowed. For this reason, the advent of videoscopes will probably only represent a significant step forward in procedures that are performed today with steerable fiberscopes (pineal biopsy, intraventricular hematoma aspiration, and so on), but should not be considered as the final solution to all of the problems and limitations of neuroendoscopy.

REFERENCES

1. Abdou MS, Cohen AR: Endoscopic treatment of colloid cysts of the third ventricle. Technical note and review of the literature. **J Neurosurg** 89:1062–1068, 1998.
2. Abdullah J, Caemaert J: Endoscopic management of craniopharyngiomas: A review of 3 cases. **Minim Invasive Neurosurg** 38:79–84, 1995.
3. Anandh B, Mohanty A, Sampath S, Praharaj SS, Kolluri S: Endoscopic approach to intraventricular cysticercal lesions. **Minim Invasive Neurosurg** 44:194–196, 2001.
4. Andoh T, Shinoda J, Miwa Y, Hirata T, Sakai N, Yamada H, Shimokawa K: Tumors at the trigone of the lateral ventricle—Clinical analysis of eight cases. **Neurol Med Chir (Tokyo)** 30:676–684, 1990.
5. Apuzzo ML, Chikovani OK, Gott PS, Teng EL, Zee CS, Giannotta SL, Weiss MH: Transcallosal, interfornicial approaches for lesions affecting the third ventricle: Surgical considerations and consequences. **Neurosurgery** 10:547–554, 1982.
6. Apuzzo ML, Dobkin WR, Zee CS, Chan JC, Giannotta SL, Weiss MH: Surgical considerations in treatment of intraventricular cysticercosis. An analysis of 45 cases. **J Neurosurg** 60:400–407, 1984.
7. Bergsneider M: Endoscopic removal of cysticercal cysts within the fourth ventricle. Technical note. **J Neurosurg** 91:340–345, 1999.
8. Bergsneider M, Holly LT, Lee JH, King WA, Frazee JG: Endoscopic management of cysticercal cysts within the lateral and third ventricles. **J Neurosurg** 92:14–23, 2000.
9. Broderick JP, Adams HP, Barsan W, Feinberg W, Feldmann E, Grotta J, Kase C, Krieger D, Mayberg M, Tilley B, Zabramski JM, Zuccarello M: Guidelines for the management of spontaneous intracerebral hemorrhage: A statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. **Stroke** 30:905–915, 1999.
10. Bucholz RD, Pittman T: Endoscopic coagulation of the choroid plexus using the Nd:YAG laser: Initial experience and proposal for management. **Neurosurgery** 28:421–427, 1991.
11. Buxton N, Vloeberghs M, Punt J: Flexible neuroendoscopic treatment of suprasellar arachnoid cysts. **Br J Neurosurg** 13:316–318, 1999.
12. Caemaert J, Abdullah J, Calliauw L, Carton D, Dhooge C, van Coster R: Endoscopic treatment of suprasellar arachnoid cysts. **Acta Neurochir (Wien)** 119:68–73, 1992.

13. Cavalheiro S, Zymberg ST, da Silva MC: Hydrocephalus in neurocysticercosis and other parasitic and infectious diseases, in Cinalli G, Maixner WJ, Sainte-Rose C (eds): *Pediatric Hydrocephalus*. Milan, Springer, 2005, pp 245–257.
14. Charalampaki P, Filippi R, Welschehold S, Perneczky A: Endoscope-assisted removal of colloid cysts of the third ventricle. **Neurosurg Rev** 29:72–79, 2006.
15. Cinalli G, Cappabianca P, de Falco R, Spennato P, Cianciulli E, Cavallo LM, Esposito F, Ruggiero C, Maggi G, de Divitiis E: Current state and future development of intracranial neuroendoscopic surgery. **Expert Rev Med Devices** 2:351–373, 2005.
16. Cinalli G, Spennato P, Cianciulli E, Fiorillo A, Di Maio S, Maggi G: The role of transventricular neuroendoscopy in the management of craniopharyngiomas: Three patient reports and review of the literature. **J Pediatr Endocrinol Metab** 19 [Suppl 1]:341–354, 2006.
17. Colli BO, Carlotti CG, Assirati JA, Machado HR, Valenca M, Amato MC: Surgical treatment of cerebral cysticercosis: Long-term results and prognostic factors. **Neurosurg Focus** 12:E3, 2002.
18. Coplin WM, Vinas FC, Agris JM, Buciuc R, Michael DB, Diaz FG, Muizelaar JP: A cohort study of the safety and feasibility of intraventricular urokinase for nonaneurysmal spontaneous intraventricular hemorrhage. **Stroke** 29:1573–1579, 1998.
19. Couldwell WT, Weiss MH, Rabb C, Liu JK, Apfelbaum RI, Fukushima T: Variations on the standard transsphenoidal approach to the sellar region, with emphasis on the extended approaches and parasellar approaches: Surgical experience in 105 cases. **Neurosurgery** 55:539–550, 2004.
20. Crimmins DW, Pierre-Kahn A, Sainte-Rose C, Zerah M: Treatment of suprasellar cysts and patient outcome. **J Neurosurg** 105 [Suppl 2]:107–114, 2006.
20a. Dandy WE: Cerebral ventriculoscopy. **Bull Johns Hopkins Hosp** 33:189, 1922.
21. D'Angelo VA, Galarza M, Catapano D, Monte V, Bisceglia M, Carosi I: Lateral ventricle tumors: Surgical strategies according to tumor origin and development—A series of 72 cases. **Neurosurgery** 56 [Suppl]:36–45, 2005.
22. de Divitiis E, Cavallo LM, Cappabianca P, Esposito F: Extended endoscopic endonasal transsphenoidal approach for the removal of suprasellar tumors: Part 2. **Neurosurgery** 60:46–59, 2007.
23. Decq P, Brugieres P, Le Guerinel C, Djindjian M, Keravel Y, Nguyen JP: Percutaneous endoscopic treatment of suprasellar arachnoid cysts: Ventriculocystostomy or ventriculocystocisternostomy? Technical note. **J Neurosurg** 84:696–701, 1996.
24. Decq P, Le Guerinel C, Brugières P, Djindjian M, Silva D, Kéravel Y, Melon E, Nguyen JP: Endoscopic management of colloid cysts. **Neurosurgery** 42:1288–1296, 1998.
25. Delitala A, Brunori A, Chiappetta F: Purely neuroendoscopic transventricular management of cystic craniopharyngiomas. **Childs Nerv Syst** 20:858–862, 2004.
26. Dusick JR, Esposito F, Kelly DF, Cohan P, DeSalles A, Becker DP, Martin NA: The extended direct endonasal transsphenoidal approach for nonadenomatous suprasellar tumors. **J Neurosurg** 102:832–841, 2005.
27. Eiras Ajuria J, Alberdi Viñas J: Endoscopic treatment of intracranial lesions. Apropos of 8 cases [in French]. **Neurochirurgie** 37:278–283, 1991.
27a. Fay T, Grant FC: Ventriculoscopy and intraventricular photography in internal hydrocephalus. **JAMA** 80:461–463, 1923.
28. Fratzoglou M, Leite dos Santos AR, Gawish I, Perneczky A: Endoscope-assisted microsurgery for tumors of the septum pellucidum: Surgical considerations and benefits of the method in the treatment of four serial cases. **Neurosurg Rev** 28:39–43, 2005.
29. Fukushima T: Endoscopic biopsy of intraventricular tumors with the use of a ventriculofiberscope. **Neurosurgery** 2:110–113, 1978.
30. Fukushima T, Ishijima B, Hirakawa K, Nakamura N, Sano K: Ventriculofiberscope: A new technique for endoscopic diagnosis and operation. Technical note. **J Neurosurg** 38:251–256, 1973.
31. Gaab MR, Schroeder HW: Neuroendoscopic approach to intraventricular lesions. **J Neurosurg** 88:496–505, 1998.
32. Gangemi M, Maiuri F, Colella G, Buonamassa S: Endoscopic surgery for pineal region tumors. **Minim Invasive Neurosurg** 44:70–73, 2001.
33. Gawish I, Reisch R, Perneczky A: Endoscopic aqueductoplasty through a tailored craniocervical approach. **J Neurosurg** 103:778–782, 2005.
34. Grunert P, Hopf N, Perneczky A: Frame-based and frameless endoscopic procedures in the third ventricle. **Stereotact Funct Neurosurg** 68:80–89, 1997.
35. Guiot G, Derome P: Indications for trans-sphenoid approach in neurosurgery. 521 cases [in French]. **Ann Med Interne (Paris)** 123:703–712, 1972.
36. Guiot G, Rougerie J, Fourestier M, Fournier A, Comoy C, Vulmiere J, Gronz R: A new endoscopic technique. Endoscopic intracranial explorations [in French]. **Presse Med** 72:1225–1231, 1963.
37. Harris AE, Hadjipanayis CG, Lunsford LD, Lunsford AK, Kassam AB: Microsurgical removal of intraventricular lesions using endoscopic visualization and stereotactic guidance. **Neurosurgery** 56 [Suppl]:125–132, 2005.
37a. Harvey AS, Freeman JL, Berkovic SF, Rosenfeld JV: Transcallosal resection of hypothalamic hamartomas in patients with intractable epilepsy. **Epileptic Disord** 5:257–265, 2003.
38. Hellwig D, Grotenhuis JA, Tirakotai W, Riegel T, Schulte DM, Bauer BL, Bertalanffy H: Endoscopic third ventriculostomy for obstructive hydrocephalus. **Neurosurg Rev** 28:1–38, 2005.
39. Horváth Z, Veto F, Balás I, Kövér F, Dóczi T: Biportal endoscopic removal of a primary intraventricular hematoma: Case report. **Minim Invasive Neurosurg** 43:4–8, 2000.
40. Iplikcioglu AC, Bek S, Gökduman CA, Bikmaz K, Cosar M: Diffuse villous hyperplasia of choroid plexus. **Acta Neurochir (Wien)** 148:691–694, 2006.
41. Jallo GI, Morota N, Abbott R: Introduction of a second working portal for neuroendoscopy. A technical note. **Pediatr Neurosurg** 24:56–60, 1996.
42. Jho HD, Ha HG: Endoscopic endonasal skull base surgery: Part 1—The midline anterior fossa skull base. **Minim Invasive Neurosurg** 47:1–8, 2004.
43. Kirollos RW, Javadpour M, May P, Mallucci C: Endoscopic treatment of suprasellar and third ventricle-related arachnoid cysts. **Childs Nerv Syst** 17:713–718, 2001.
44. Kondziolka D, Lunsford LD: Microsurgical resection of colloid cysts using a stereotactic transventricular approach. **Surg Neurol** 46:485–492, 1996.
45. Konovalov AN: Microsurgery of tumours of diencephalic region. **Neurosurg Rev** 6:37–41, 1983.
46. Kunwar S: Endoscopic adjuncts to intraventricular surgery. **Neurosurg Clin N Am** 14:547–557, 2003.
47. Lagares A, Putman CM, Ogilvy CS: Posterior fossa decompression and clot evacuation for fourth ventricle hemorrhage after aneurysmal rupture: Case report. **Neurosurgery** 49:208–211, 2001.
48. Laws ER, Kanter AS, Jane JA Jr, Dumont AS: Extended transsphenoidal approach. **J Neurosurg** 102:825–828, 2005.
49. Lewis AI, Crone KR, Taha J, van Loveren HR, Yeh HS, Tew JM: Surgical resection of third ventricle colloid cysts. Preliminary results comparing transcallosal microsurgery with endoscopy. **J Neurosurg** 81:174–178, 1994.
50. Longatti P, Fiorindi A, Di Paola F, Curtolo S, Basaldella L, Martinuzzi A: Coiling and neuroendoscopy: A new perspective in the treatment of intraventricular haemorrhages due to bleeding aneurysms. **J Neurol Neurosurg Psychiatry** 77:1354–1358, 2006.
51. Longatti P, Fiorindi A, Martinuzzi A: Neuroendoscopic aspiration of hematocephalus totalis: Technical note. **Neurosurgery** 57 [Suppl]:E409, 2005.
52. Longatti PL, Martinuzzi A, Fiorindi A, Maistrello L, Carteri A: Neuroendoscopic management of intraventricular hemorrhage. **Stroke** 35:E35–38, 2004.
53. Luther N, Cohen A, Souweidane MM: Hemorrhagic sequelae from intracranial neuroendoscopic procedures for intraventricular tumors. **Neurosurg Focus** 19:E9, 2005.
54. Macarthur DC, Buxton N, Punt J, Vloeberghs M, Robertson IJ: The role of neuroendoscopy in the management of brain tumours. **Br J Neurosurg** 16:465–470, 2002.
55. Mathiesen T, Grane P, Lindgren L, Lindquist C: Third ventricle colloid cysts: A consecutive 12-year series. **J Neurosurg** 86:5–12, 1997.
56. Matula C, Reinprecht A, Roessler K, Tschabitscher M, Koos WT: Endoscopic exploration of the IVth ventricle. **Minim Invasive Neurosurg** 39:86–92, 1996.
57. McCullough DC, Epstein F: Optic pathway tumors. A review with proposals for clinical staging. **Cancer** 56 [Suppl]:1789–1791, 1985.
57a. Mixter WJ: Ventriculoscopy and puncture of the floor of the third ventricle. **Boston Med Surg J** 188:277–278, 1923.

58. Morota N, Fujiyama Y: Endoscopic coagulation of choroid plexus as treatment for hydrocephalus: Indication and surgical technique. **Childs Nerv Syst** 20:816–820, 2004.
58a. Ng YT, Rekate HL, Prenger EC, Chung SS, Feiz-Erfan I, Wang NC, Varland MR, Kerrigan JF: Transcallosal resection of hypothalamic hamartoma for intractable epilepsy. **Epilepsia** 47:1192–1202, 2006.
59. Nicolato A, Foroni R, Rosta L, Gerosa M, Bricolo A: Multimodality stereotactic approach to the treatment of cystic craniopharyngiomas. **Minim Invasive Neurosurg** 47:32–40, 2004.
60. Nishihara T, Nagata K, Tanaka S, Suzuki Y, Izumi M, Mochizuki Y, Akabane A, Ochiai C: Newly developed endoscopic instruments for the removal of intracerebral hematoma. **Neurocrit Care** 2:67–74, 2005.
61. Nishihara T, Teraoka A, Morita A, Ueki K, Takai K, Kirino T: A transparent sheath for endoscopic surgery and its application in surgical evacuation of spontaneous intracerebral hematomas. Technical note. **J Neurosurg** 92:1053–1055, 2000.
62. O'Brien DF, Hayhurst C, Pizer B, Mallucci CL: Outcomes in patients undergoing single-trajectory endoscopic third ventriculostomy and endoscopic biopsy for midline tumors presenting with obstructive hydrocephalus. **J Neurosurg** 105 [Suppl]:219–226, 2006.
63. Oi S, Abdullah SH: New transparent clear peel-away sheath for various neuroendoscopic procedures. Technical note. **J Neurosurg** 107:1244–1247, 2007.
64. Oi S, Shibata M, Tominaga J, Honda Y, Shinoda M, Takei F, Tsugane R, Matsuzawa K, Sato O: Efficacy of neuroendoscopic procedures in minimally invasive preferential management of pineal region tumors: A prospective study. **J Neurosurg** 93:245–253, 2000.
65. Oka K, Yamamoto M, Nagasaka S, Tomonaga M: Endoneurosurgical treatment for hydrocephalus caused by intraventricular tumors. **Childs Nerv Syst** 10:162–166, 1994.
66. Pepin SM, Lessell S: Anterior visual pathway gliomas: The last 30 years. **Semin Ophthalmol** 21:117–124, 2006.
67. Peretta P, Ragazzi P, Galarza M, Genitori L, Giordano F, Mussa F, Cinalli G: Complications and pitfalls of neuroendoscopic surgery in children. **J Neurosurg** 105 [Suppl]:187–193, 2006.
68. Perneczky A, Fries G: Endoscope-assisted brain surgery: Part 1—Evolution, basic concept, and current technique. **Neurosurgery** 42:219–225, 1998.
69. Pople IK, Athanasiou TC, Sandeman DR, Coakham HB: The role of endoscopic biopsy and third ventriculostomy in the management of pineal region tumours. **Br J Neurosurg** 15:305–311, 2001.
70. Putnam TJ: Treatment of hydrocephalus by endoscopic coagulation of the choroid plexus: description of a new instrument and preliminary report of results. **N Engl J Med** 210:1373–1376, 1934.
71. Robinson S, Cohen AR: The role of neuroendoscopy in the treatment of pineal region tumors. **Surg Neurol** 48:360–367, 1997.
72. Rodziewicz GS, Smith MV, Hodge CJ: Endoscopic colloid cyst surgery. **Neurosurgery** 46:655–662, 2000.
73. Schroeder HW, Gaab MR: Endoscopic resection of colloid cysts. **Neurosurgery** 51:1441–1445, 2002.
74. Siomin V, Constantini S: Treatment of hydrocephalus in suprasellar lesions, in Cinalli G, Maixner WJ, Sainte-Rose C (eds): *Pediatric Hydrocephalus*. Milan, Springer, 2004, pp 163–170.
75. Souweidane MM: Endoscopic surgery for intraventricular brain tumors in patients without hydrocephalus. **Neurosurgery** 57:312–318, 2005.
76. Souweidane MM, Sandberg DI, Bilsky MH, Gutin PH: Endoscopic biopsy for tumors of the third ventricle. **Pediatr Neurosurg** 33:132–137, 2000.
77. Spaziante R, de Divitiis E, Irace C, Cappabianca P, Caputi F: Management of primary or recurring grossly cystic craniopharyngiomas by means of draining systems. Topic review and 6 case reports. **Acta Neurochir (Wien)** 97:95–106, 1989.
78. Tamburrini G, Caldarelli M, Di Rocco F, Massimi L, D'Angelo L, Fasano T, Di Rocco C: The role of endoscopic choroid plexus coagulation in the surgical management of bilateral choroid plexuses hyperplasia. **Childs Nerv Syst** 22:605–608, 2006.
79. Teo C, Nakaji P: Neuro-oncologic applications of endoscopy. **Neurosurg Clin N Am** 15:89–103, 2004.
80. Terasaki M, Uchikado H, Takeuchi Y, Shigemori M: Minimally invasive management of ependymoma of the aqueduct of Sylvius: Therapeutic considerations and management. **Minim Invasive Neurosurg** 48:322–324, 2005.
81. Tirakotai W, Riegel T, Schulte DM, Bertalanffy H, Hellwig D: Neuroendoscopic stent procedure in obstructive hydrocephalus due to both foramina of Monro occluding craniopharyngioma: Technical note. **Surg Neurol** 61:293–296, 2004.
82. Wang JC, Heier L, Souweidane MM: Advances in the endoscopic management of suprasellar arachnoid cysts in children. **J Neurosurg** 100:418–426, 2004.
83. Warf BC: Comparison of endoscopic third ventriculostomy alone and combined with choroid plexus cauterization in infants younger than 1 year of age: A prospective study in 550 African children. **J Neurosurg** 103:475–481, 2005.
84. Warf BC: Hydrocephalus in Uganda: The predominance of infectious origin and primary management with endoscopic third ventriculostomy. **J Neurosurg** 102 [Suppl 1]:1–15, 2005.
85. Weiss M: The transnasal transsphenoidal approach, in Apuzzo MLJ (ed): *Surgery of the Third Ventricle*. Baltimore, Williams & Wilkins, 1987, pp 476–494.
86. Yaşargil MG: Craniopharyngiomas, in Yaşargil MG (ed): *Microneurosurgery, Volume 4B, Microneurosurgery of CNS Tumors.* Stuttgart, Georg Thieme Verlag, 1996, pp 205–223.
87. Yurtseven T, Ersahin Y, Demirtas E, Mutluer S: Neuroendoscopic biopsy for intraventricular tumors. **Minim Invasive Neurosurg** 46:293–299, 2003.

Acknowledgments

We are deeply indebted to Felice Esposito, M.D., Ph.D., for his invaluable contributions to the production of this article.

COMMENTS

The end of the 20th century has been a revolutionary time in the evolution of neurosurgical technique. Several areas of research have converged, including computer miniaturization and speed, which facilitated the propagation of stereotaxis, along with advances in optics and instrumentation that have permitted the rise of neuroendoscopy into common neurosurgical practice. Simultaneously, the general philosophy of "minimal access surgery," that "less truly is more" when it comes to approaches, has led us to a new era in which the neurosurgical playing field is clearly changing. Just as interventional neuroradiology has dramatically affected vascular neurosurgery, so too is neuroendoscopy beginning to have a marked impact across all fields of neurosurgery. Certainly, none of these neuroendoscopic techniques are really "new" in the sense of a Kuhnian revolution in thought, but enough time has passed that the instrument companies are investing money in pushing these techniques further into practice, which facilitates the ability of innovative thinkers to introduce minimal access neuroendoscopy into the treatment of a wide variety of neurological pathologies and multiple intracerebral locations.

This article provides an outstanding overview of the neuroendoscopic approaches to the ventricles. Written by experts in the field, each section contains pearls of wisdom, smoothed over years of trial and error. This article will serve as a "crash course" to readers who perhaps are not familiar with the range of available neuroendoscopic approaches to the ventricles. Additionally, this article will serve to stimulate young, fresh minds to continue to push the frontiers of minimal access surgery into the 21st century. Absent from these articles are discussions of the more innovative techniques in neuroendoscopy, such as three-dimensional endoscopy, virtual endoscopy, integration with robotics, and intraoperative magnetic resonance imaging. What does the future hold? How about intrathecal injection of self-assembling nanoparticles that navigate the ventricular system, form a camera, and biopsy intraventricular lesions (1)?

Theodore H. Schwartz
New York, New York

1. Maheshwari V, Saraf RF: High-resolution, thin-film device to sense texture by touch. **Science** 312:1501–1504, 2006.

This review article is an excellent synopsis presented by very experienced neurosurgeons from many parts of the world who use the endoscope in their daily neurosurgical practices. It includes a great variety of lesions that are located in all areas of the ventricular system of the brain. The article nicely demonstrates the evolution from a technical challenge in earlier days to a gold standard in some of the most frequent neurosurgical procedures. The article's setup, with Patient Selection, Surgical Instruments, and Endoscopic Technique, provides readers with a fast overview of each described lesion. The technical descriptions contain valuable surgical references. It is of particular benefit that all authors have summarized their experience in a small abstract dedicated to a particular lesion. This provides, especially to the inexperienced reader, useful knowledge and, in many instances, helps with identifying adequate surgical alternatives. This international group of outstanding neurosurgeons has provided another valuable summary of modern neuroendoscopic procedures within the cerebral ventricles.

Oliver Bozinov
Helmut Bertalanffy
Zurich, Switzerland

This article represents a significant amount of work by the authors and encapsulates an evolving body of literature focused on the management of intraventricular disease using endoscopy. The article addresses the management of a heterogeneous group of pathologies in children and adults. This is an excellent and thorough review, and the author list resembles a "who's who" of intraventricular endoscopy. It will be interesting to follow this work over the next decade as the technology continues to evolve with the integration of frameless stereotaxy and new forms of visualization. In particular, the use of chip-tip technology, which may substantially obviate some of the limitations of existing fiber-optic endoscopy, holds the potential for even greater advances.

In our experience, the greatest limitation to addressing some of the larger lesions via fiber-optic, through-channel endoscopy has been the inability to use true bimanual microsurgical dissection techniques as well as the need to work in a fluid medium as opposed to an air medium. We have found that this is best overcome with the use of endoport conduit surgery (1). This involves the application of a conduit, as originally described by Morita and Kelly (2), with a cylindrical retractor using a dilator system. This system allows the rod-lens endoscope to be inserted freely, and it facilitates true bimanual microsurgical technique under direct endoscopic visualization in an air medium. This technique has been referred to as endoport surgery, and may have an emerging role in future intraventricular and intra-axial surgery.

Daniel M. Prevedello
Paul A. Gardner
Amin B. Kassam
Pittsburgh, Pennsylvania

1. Harris AE, Hadjipanayis CG, Lunsford LD, Lunsford AK, Kassam AB: Microsurgical removal of intraventricular lesions using endoscopic visualization and stereotactic guidance. **Neurosurgery** 56 [Suppl]:125–132, 2005.
2. Morita A, Kelly PJ: Resection of intraventricular tumors via a computer-assisted volumetric stereotactic approach. **Neurosurgery** 32:920–926, 1993.

The breadth of the application of neuroendoscopy to intraventricular lesions is outlined in this work by a large number of authors regarded as experts in the field, with excellent illustrations and video examples of the techniques. Many of the described techniques are at the frontiers of this field, including complete resection of tumors in patients with normal-sized ventricles. As the authors indicate, these are very carefully selected patients with tumor size, intraventricular location, and vascularity specific for this technique. Although not emphasized, complications in this type of surgery may be significant, and surgeons approaching the more difficult lesions will want appropriate training and expertise.

James M. Drake
Toronto, Canada