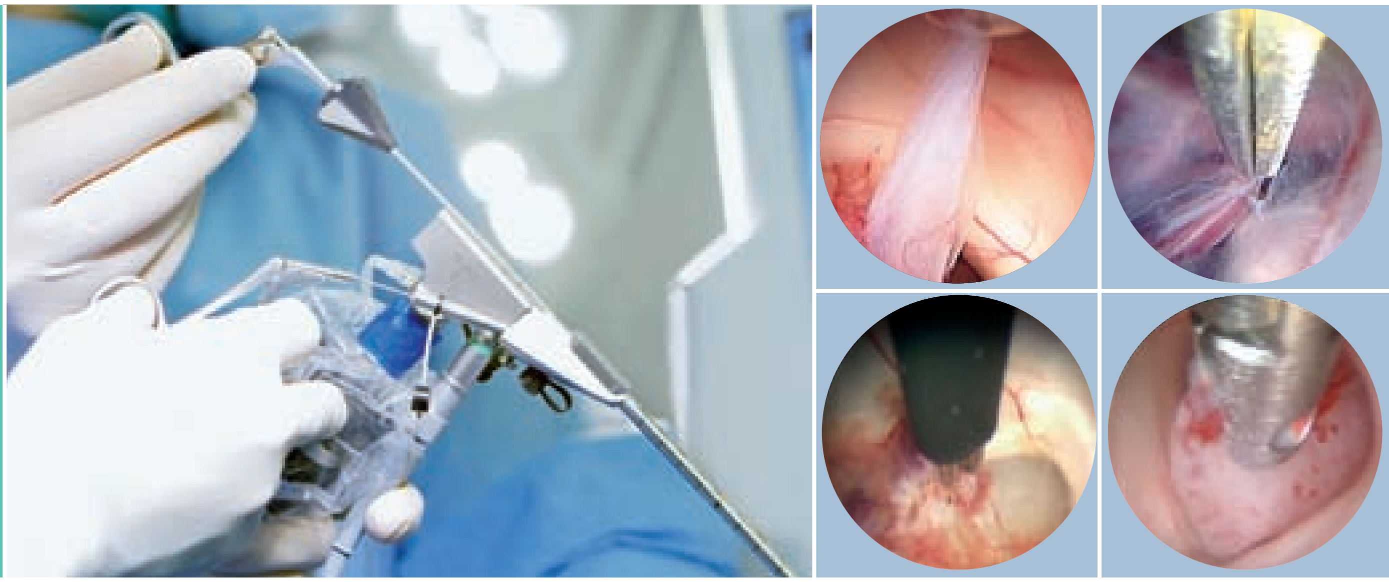
Aesculap® MINOP®

Intraventricular Neuroendoscopy:
A Practical Atlas

Mark M. Souweidane, M.D., F.A.C.S., F.A.A.P.



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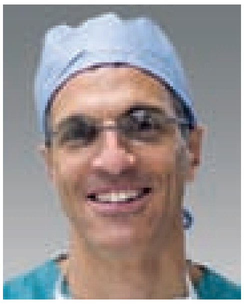
MINOP
Intraventricular Neuroendoscopy: A Practical Atlas



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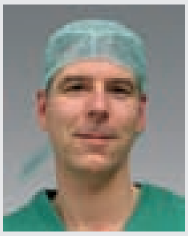
Testimonial

" Intracranial endoscopy has been a significant part of neurosurgery for the last two decades. HD and the development of new instruments has led to new possibilities in intraventricular and paraventricular surgery for the treatment of hydrocephalus, cyst fenestration or tumor biopsy / removal. The MINOP system has been a useful and reliable tool for many years. Now it will answer new demands.
Mark Souweidane is a well recognized expert in endoscopic neurosurgery. He has been part of the team developing and improving the new MINOP system. I am convinced that this endoscopy system will be of benefit for our patients and will lead to enthusiasm and satisfaction among the users."

Michael J. Fritsch
Greifswald, Germany



" This atlas on intraventricular endoscopy demonstrates in a very comprehensive and beautifully illustrated manner the range of application and brilliant visualization of the "MINOP" system. In the main sections of the atlas, endoscopic management of hydrocephalus, cysts, and tumors is described in detail based on contemporary clinical examples illustrated didactically with high quality images. In addition the reader gets information on indications, diagnostic work-up, surgical technique, and outcome. Sections on basic issues such as equipment, principles, approach and closure as well as intraventricular endoscopic anatomy are also included. In particular, the combination of navigation and endoscopy, a technique Mark is a well recognized expert in throughout the world, is shown. This atlas really is a great help for beginners as well as the advanced neuroendoscopist and may be utilized for teaching on all levels. Based on my personal experience, I recommend the MINOP system without any restrictions and congratulate the author for this beautiful and illustrative atlas, which really makes intraventricular endoscopic surgery much safer."

Nikolai J. Hopf
Stuttgart, Germany

" For neurosurgeons who are constantly striving not simply to be contemporary, but to push the limits of what can be done, Dr. Souweidane's summation of the capabilities of neuroendoscopy, as presented in this volume, comes as a welcome reminder of how far we already have come. This volume provides an excellent treatment of a range of neuroendoscopic procedures that will be welcomed by the novice and experienced endoscopist alike. There are many pearls within. As Dr. Souweidane points out, the field is still young, and many hurdles yet remain for achieving the best possible outcome for our patients. Only with mastery of both the tools and techniques of the field can progress be painstakingly extracted by the next generation of neuroendoscopist. Dr. Souweidane is to be congratulated for sharing his experience: this current and germane work makes a fine contribution to anyone striving towards that goal."

Peter Nakaji
Phoenix, USA

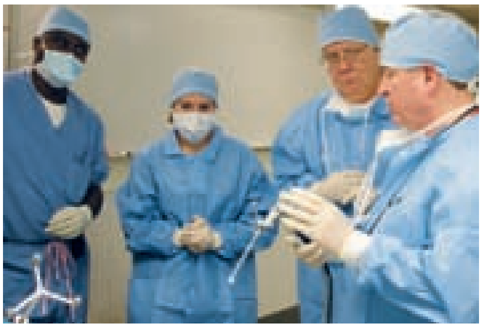
"Pre-condition of intracranial neuroendoscopy is a valuable and user-friendly endoscopic equipment. However, despite of availability of dedicated systems, the endoscopic technique is not in routine use everywhere and neurosurgeons are often hesitant to use it. The cause of the aversion is often the steep learning curve, especially by intraventricular applications. This practical atlas is a valuable support to neurosurgeons giving in-depth instructions for newcomers as well as advanced users. General principles, dedicated endoscopic systems and endoscopic applied anatomy are described in a compact and comprehensive way. Operative cases from an outstanding endoscopic surgeon illustrate the most frequent clinical applications, thus giving advantageous tips in the everyday application of intraventricular neuroendoscopy. Congratulations Mark!"

Robert Reisch
Zurich, Switzerland

"With this practical atlas on intraventricular neuroendoscopy, Mark Souweidane has created a masterpiece; small yet comprehensive, and beautifully illustrated, clearly demonstrating his vast and superb experience in this field. What I personally like most is the thoughtful and logical build-up of this atlas. It starts with an introduction emphasizing the necessity of training in this field. This is exactly what Mark does as director or faculty member in numerous neuroendoscopy courses around the world. The equipment is described, showing the importance of such excellent image quality as can be achieved with the MINOP system displayed here. Next, Mark discusses such issues as patient positioning, room orientation, techniques of hemostasis and wound closure, in which he shares all his personal pearls. The concise description of the pertinent ventricular anatomy is followed by an unmatched clear and concise description of the most frequent neuroendoscopic procedures. Starting with hydrocephalus, followed by all types of cysts and finally the ventricular tumors (most prominently colloid cysts and pineal lesions). I have thoroughly enjoyed reading this atlas. From my own +20 years experience in neuroendoscopy, I can only confirm all the technical and clinical remarks in this atlas, especially the ease of use and quality of imaging that the present MINOP system offers to both the novice and experienced neuroendoscopist. This atlas will receive a prominent place on my bookshelf."

André Grotenhuis
Nijmegen, The Netherlands

Introduction



The genesis of endoscopic surgery within the ventricular compartment can be attributed to the development of small caliber rod lens optics and fiberoptic light transmission. Since the advent of intraventricular endoscopic surgery, neurosurgeons have applied the technology to treat a number of disorders. While the enthusiasm has been great and the full potential not yet realized, a major benefit to the patient has been proven for select conditions. Most notably the treatment of noncommunicating hydrocephalus, management of patients with pineal region tumors, fenestration of intracranial cysts, and removal of colloid cysts have all been shown to provide significant benefit and reduced morbidity compared with conventional treatment strategies.

The benefit in minimally invasive endoscopic procedures is analogous to that of any endoscopic procedure, namely minimal tissue disruption, enhanced visualization, improved cosmetic results, shorter hospital stay, and less surgical morbidity. Additionally, in the neurosurgical arena, the ability to avoid shunt hardware is a major advantage owing to the life-long morbidity associated with implanted silastic devices. The surgeon willing to utilize intraventricular endoscopic surgery is first responsible for attaining a considerable degree of familiarity with the technology, relevant anatomy, and the surgical procedures. Given the relative nascence of the field, the discipline is only now being commonly implemented in training programs. Hence, for those that have not had the opportunity to have endoscopic surgery as part of their formal training, it is strongly recommended that the surgeon participate in established practical courses in endoscopic neurosurgery (Figs. 1–4). It is also recommended that initial excursions in the realm of intraventricular neuroendoscopy be limited to relatively simple procedures. Once fluent with the endoscopic equipment, more advanced procedures can be performed with greater familiarity and experience. It is anticipated with future generations of neurosurgeons that the endoscope will be an indispensable part of the neurosurgeon's armamentarium given the unmatched image resolution and minimal invasive qualities. This foreseeable integration will expectantly be paralleled with continued evolution in compatible equipment to suit the needs of an expanding repertoire.

Figs. 1–4 *Practical courses in endoscopic neurosurgery offer the participant a balanced exposure to didactic sessions, one-on-one interactions with experienced surgeons, hands-on instruction with equipment, and practical surgical techniques with cadavers.*

Equipment

Few neurosurgical procedures demand a degree of familiarity with equipment as do neuroendoscopic techniques. This feature is somewhat explained by the recent introduction of the neuroendoscope as well as the delicate nature of the equipment. It is mandatory that the surgeon be well versed with all components prior to use. As mentioned previously, this familiarity is readily gained through practical courses in neuroendoscopy. The basic components of any neuroendoscopic procedure include the endoscope and sheath, a camera, a light source, compatible instrumentation, and a monitor.

Endoscope Two main types of endoscopes are available; fiberoptic and rod lens systems. While the fiberoptic endoscopes possess some advantages including lower cost, malleability, multi-directional capability (steerable), and ease of use, a solid lens endoscope provides unprecedented image resolution and light transmission. This resolution has recently been enhanced with high-definition (HD) cameras and monitors. Although the image resolution afforded by solid lens scopes is superior, these endoscopes are more delicate and more costly. A reduced diameter of the solid lens endoscope is appealing with regard to intraventricular surgery, but the image resolution and light transmission decrease with smaller scope dimensions. An important variable in endoscope design is the directional aspect of the lens. Angled endoscopes are appealing in the limited ventricular compartment since they enhance the viewing capacity. Their use however is less intuitive owing to the offset of the viewing plane from the linear axis of the endoscope. Further, the directional capacity of the working instruments does not match the viewing angle.

With regard to selecting an endoscope, the desired characteristics are a function of the intended use. As an example, for diagnostic ventriculoscopy or catheter placement, a non-channeled fiberoptic scope would be adequate. For more complex procedures including colloid cyst removal or cyst fenestrations, a rod lens endoscope with multiportal capacity is preferred. Since complications that are attributed the larger bore sheaths and endoscope are highly unusual, solid lens systems are favored for nearly all intraventricular surgery.

The cost associated with dedicated neuroendoscopy should not serve as a deterrent. Most equipment for endoscopic procedures such as endoscopic third ventriculostomy (ETV) and septal fenestration can readily be accomplished using endoscopes designed for other disciplines (i.e. urology and otolaryngology). The majority of cases including ETV, tumor biopsy, and septal fenestrations can be accomplished using a 3–4 mm pediatric cystoscope. When investing in dedicated endoscopes for neurosurgical applications, it is wise to maintain a backup system of lenses due to the all too frequent event of equipment malfunction.

Sheath Most intraventricular endoscopy is performed through a sheath. A sheath insures that the endoscope can be repeatedly placed into the ventricular compartment without added tissue injury. They are also important devices that make initial ventricular cannulation less traumatic given their blunt tips. Sheaths are, for the most part, now integrated into reusable devices as matched components of most commercially available neuroendoscopes. The sheath design dictates many features of the endoscopic system including the size of compatible equipment, the number of portals, and the capability to integrate other technologies (i.e. stereotaxy and endoscope holders). At a minimum, if one is to perform more than diagnostic ventriculoscopy (fenestrations, tumor biopsy/removal) a portal for irrigation, fluid egress and a surgical instrument are requisite. The dimensions of these portals and their orientation with the axis of the sheath will dictate which instruments are compatible. In general, larger working portals offer greater versatility of instruments. A working portal that has a diameter of 2 mm or greater with a parallel orientation is very beneficial if intraventricular tumor surgery is intended.

Camera To maximize the capacity of rod lenses, a charged coupling device (CCD) camera is preferred. Most cameras have universal fittings for endoscopes and coupling devices are seldom needed. One particular feature that is beneficial is an automatic adjusting aperture. The varying light reflectance within the ventricular compartment is best compensated for with an automatic light adjustment rather than a requirement of an operating room assistant to manually adjust the light source intensity.

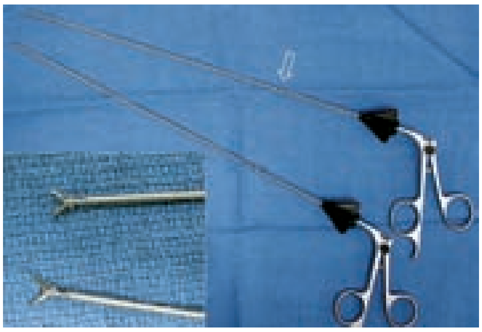
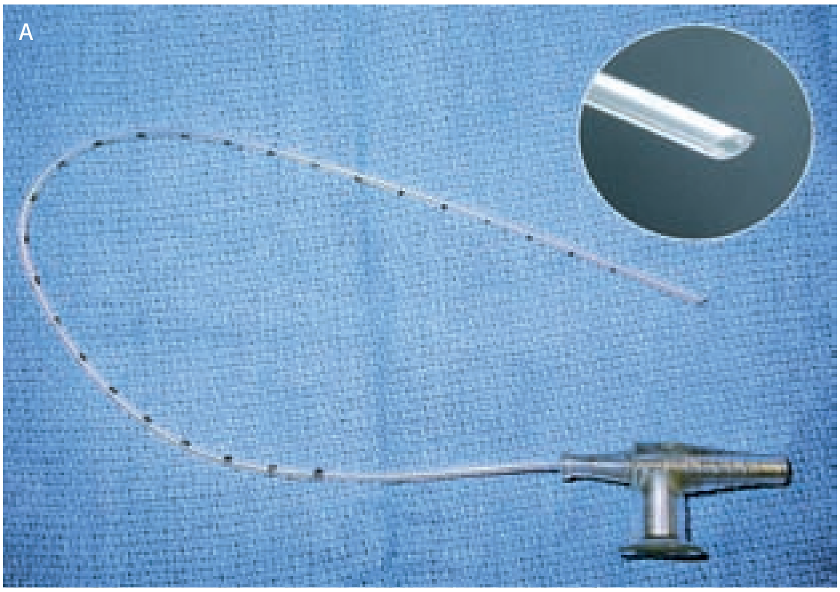


Fig. 5 *Dual action endoscopic scissors and cupped biopsy forceps. The arrow indicates a precalibrated mark that matches the length of the working portal.*

Compatible Instrumentation A host of compatible instruments have been designed for the expanding filed of endoscopic surgery. At the least, if tumor or complex cyst management is anticipated, these instruments should include monopolar and bipolar electrocautery, scissors, cupped biopsy forceps, grasping forceps, and suction aspirators (Figs. 5, 6). Embolectomy catheters are commonly used for accomplishing third ventriculostomies, cyst fenestrations, and hemostasis (Fig. 7). Using small volume syringes (1-3 cc) filled with saline offers a more controlled ability to inflate and deflate the balloon. A very appealing feature of some instruments is a rotational capability through a coaxial system thus eliminating the need for hand rotation and reducing excessive movement of the endoscope (Fig. 8).

Irrespective of the instrument, graduated markings or precalibrated indicators on the shaft are important in providing the surgeon knowledge as to when the instrument will enter the endoscopic field (Fig. 5). With this information, the speed of passing instruments can be gauged accordingly. If not present on the instrument these markings should be placed with a marking pen or adhesive strips.



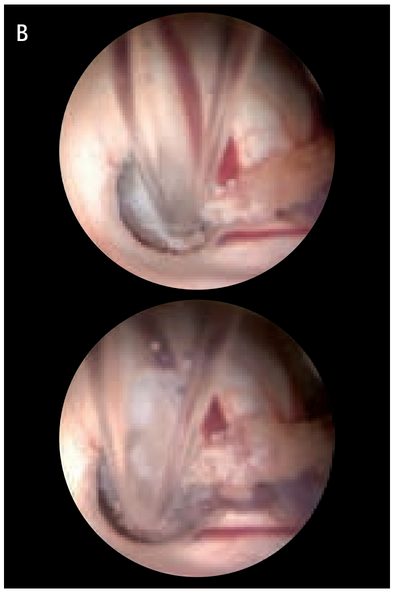


Fig. 6A *This figure shows a 6 Fr endotracheal suction aspirator that is used in intraventricular endoscopy. The see-though plastic tubing with graduations are appealing features. The device is modified by removing the distal fenestrations (inset).*

Fig. 6B *Endoscopic view of a clear suction cannula prior to the application of suction (top) and during the evacuation of colloid cyst contents (bottom). The clarity of the cannula allows the surgeon to directly monitor and adjust the degree of suction if any surrounding tissue such as choroid plexus is affected.*

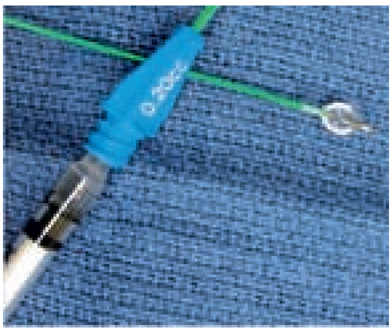


Fig. 7 *A 3 Fr embolectomy catheter is commonly used for enlarging ETV stomas and septal/cyst fenestrations.*

Fig. 8 *The collar at the back end of the forceps allows a rotation of the device tips without rotating the grips, an important and easy to use feature that avoids excessive endoscopic movements.*

General Principles of Intraventricular Endoscopic Surgery

Patient Position and Room Orientation

Three principle features should always be integrated into positioning the patient who is to undergo intraventricular endoscopic surgery. First the planned entry site should represent the highest point of the patient. This reverse-Trendelenberg position is used to minimize CSF egress and ventricular collapse once cannulation occurs. Second, the bed height should be adjusted to compensate for the added working length of the endoscope and compatible instrumentation. The need to pass instruments into the endoscopic sheath necessitates that the bed position be low enough to avoid these instruments passing in close proximity to the surgeon's face. Some of this problem is also minimized by the surgeon being positioned just to the left of the patient's head (assuming right handedness). Last, all monitors which will transmit the endoscopic or navigational image are positioned at the foot of the bed. This avoids the need for the surgeon to constantly turn thus minimizing inadvertent scope movements (Figs. 9–11).

Fig. 9 *The operating room is arranged such that all monitors are at the foot of the patient, the surgeons stand on either side of the head, and the scrub nurse is opposite the anesthesiologist out of the line of sight.*

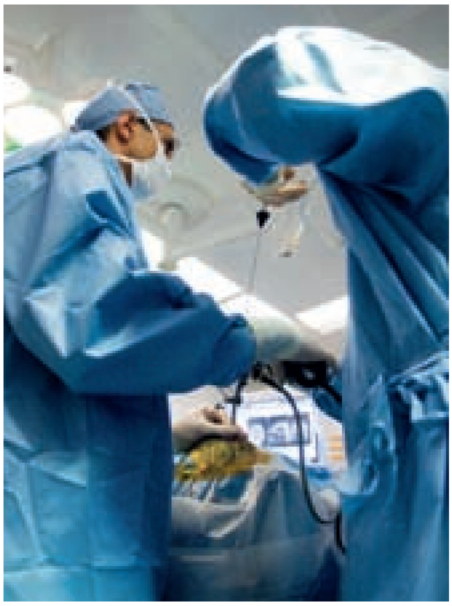


Fig. 10 *The surgeons stand on either side of the head to create an unhindered zone in which to pass instruments into the working portals. The bed is also lowered to ease the placement of instruments into the working portal.*

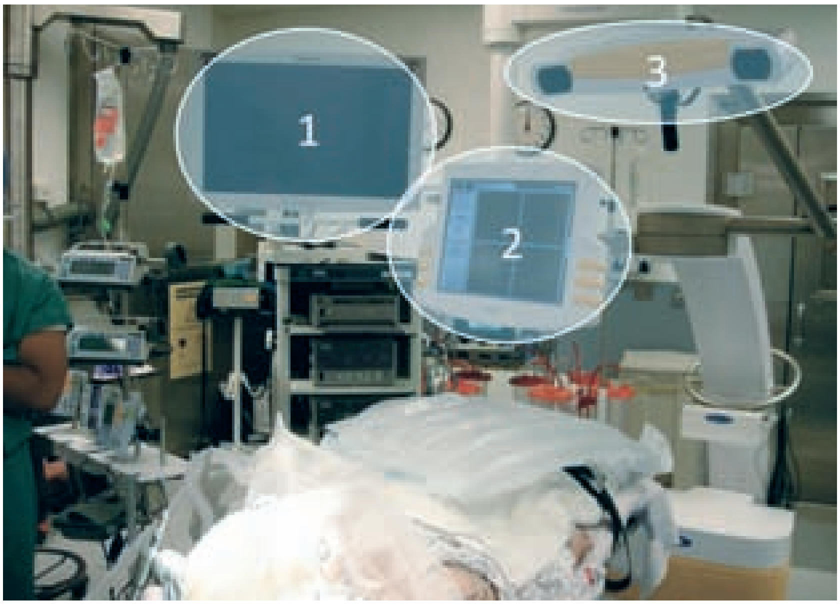


Fig. 11 *When using integrated navigational guidance an unobstructed line of sight needs to be maintained between the surgeon and the (1) endoscopic monitor, (2) the navigation monitor, and (3) the infrared camera for stereotactic guidance.*

Navigational Guidance

Surgical planning is crucial to successful intraventricular endoscopic surgery. For each procedure the surgeon should emphasize the selection of an entry site, the endoscopic path, and the surgical goal (Fig. 12).

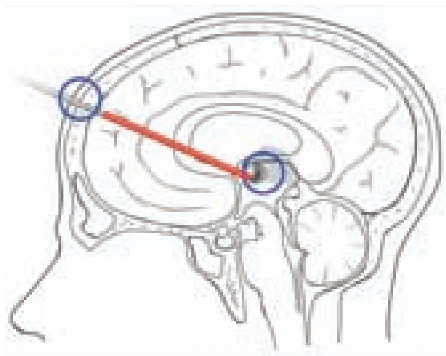


Fig. 12 *Surgical planning focuses on the entry site, the endoscope path, and the surgical goal. This diagram depicts an optimal trajectory for a lesion at the roof of the third ventricle. The entry site (blue circle) is chosen to avoid a sulcus, the endoscopic path (red line) clears the caudate nucleus and fornix, and the target (blue circle) is best visualized with an anterior approach using an angled lens.*

- **Entry Site** While most ventricular cannulation is quite simple given that the majority of patients have concomitant hydrocephalus, navigation is helpful for several reasons. Venrtriculomegaly should not mislead one to believe that ventricular cannulation will be simple. Because most endoscopic sheaths are several millimeters in diameter errant endoscopic paths can have harmful results. Additionally, many trajectories used in endoscopic surgery rely on unconventional entry sites (septal fenestration, colloid cyst removal, pineal region tumor biopsy/resection, etc.), burr hole positions are frequently used that are not typical for ventricular cannulation. Further, if intraventricular endscopy is ever planned on a patient with normal sized ventricles, then guidance is an essential component of surgery. Lastly, an entry site should always be selected that avoids a sulcus, a potentially dangerous location for endoscope passage. Selecting the best entry site is easily accomplished through the use of stereotactic guidance.

- **Surgical Trajectory** A surgical trajectory should be selected that minimizes the need to torque once within the ventricular compartment. While

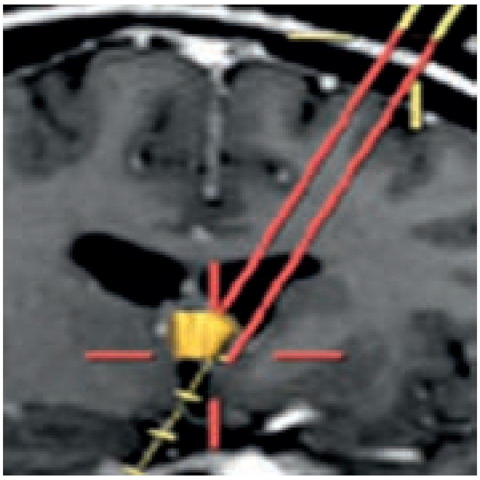


Fig. 13 *A helpful feature of some surgical planning software allows the dimension of the endoscope or sheath to be visualized thus offering an accurate estimation of the surgical path. This feature is very helpful when working in smaller ventricles as shown in the image.*

minimal adjustments are always necessary once within the ventricular compartment, these maneuvers and any inherent risk of hemorrhage can be reduced substantially be preselecting an optimal surgical path. Planning a trajectory also will reduce the risk of injury to periventricular structures (caudate head, fornix, internal capsule, etc.). Ideally, a surgical plan is created preoperatively and then used in real time for passing the endoscopic sheath. The best planning software allows the endoscope or the endoscopic sheath dimension to be superimposed into the plan (Fig. 13). This ability takes the full dimension of the device into consideration and avoids the misleading impression that the sheath is as small as the trajectory lines on stereotactic planning images.

- **Surgical Goal** The intented surigcal goal will dictate the optimal direction toward the surgical target. As an example, the trajectory may vary significantly between an intended biopsy compared with attempted removal of a pineal region tumor. Clear visualization of the surgical target with minimal to no scope movements should be always be the goal. This is accomplished with trajectory planning and angled endoscopes.

When integrating navigational guidance with endoscopic surgery there are several points worth emphasizing. First, the tracking device for optically-guided stereotactic navigation should be attached to a reinforced aspect of the endoscopic sheath or base. If the tracking device is attached to cylindrical aspect of the sheath, crimping can be avoided by reinforcing the sheath with a collar (Fig. 14). Alternatively, the device can be attached to the base of the endoscope or coupling device. Second, it is important to position the reference array as far from the tip of the endoscope as possible to avoid

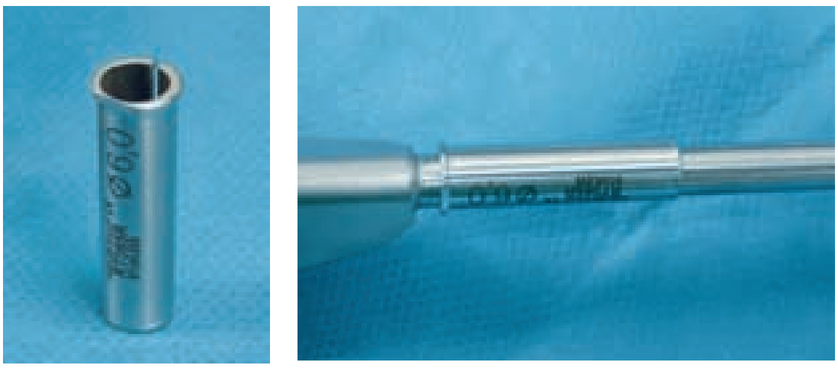


Fig. 14 *When attaching a stereotactic reference array to the sheath of the endoscope a reinforced collar (left) should be used. The collar is placed as far back as possible on the sheath (right) so that the functional working length is maximized.*

decreasing the functional working length of the sheath (Fig. 15). Lastly, an array is selected that does not interfere with the ability to easily reach the working portals Fig. 16).

Fig. 15 *The tracking device for optically-guided stereotactic navigation is attached to back of the system to maintain an adequate working length.*

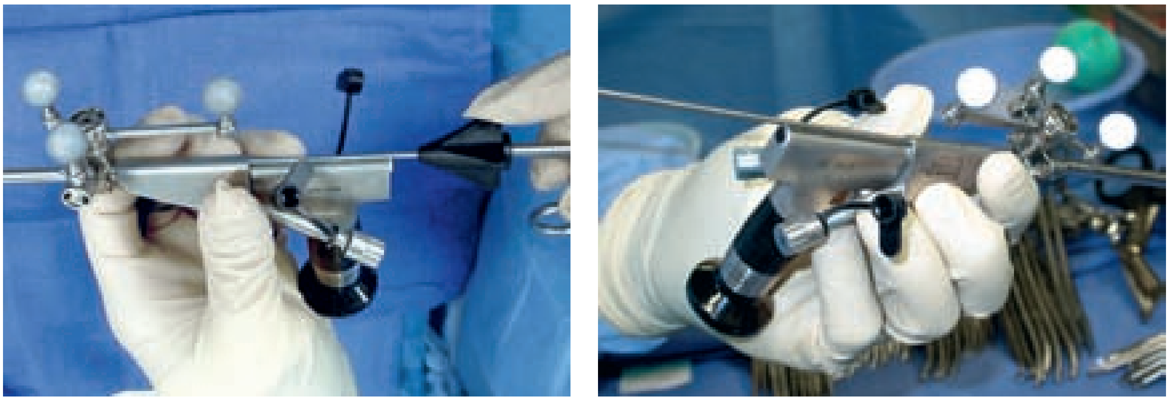


Fig. 16 *With the use of tracking devices for navigation it is important to position these devices so that they will not interfere with access to the endoscopic working portals.*

Irrigation

Irrigation with a warmed isotonic solution such as lactated Ringers is typically recommended to decrease any potential for electrolyte or temperature disturbance. The control of irrigation can be performed via hand-held syringes, motor driven pumps, or by gravitation, the choice being governed by cost and surgeon preference. One simple and effective method that does not rely on pumps or foot pedals is to use a constant inflow from an intravenous bag elevated approximately 15 cm above the surgical site. Whichever method is used, it is essential that an exit portal be maintained open at all times so that the volume of inflow will continuously match the volume of outflow. This matched irrigation practice will avoid over insufflating the ventricular compartment and unwanted elevations of intracranial pressure. The instrument portal should not serve as the only method in which irrigation exits the ventricular compartment since this is temporarily occluded when passing instruments (Figs. 17, 18).

Scope Holder

Scope holders have gained mixed approval by neurosurgeons. Several excellent holders have been designed that are easy to use with little of the

Fig. 17 *Continuous irrigation is accomplished by attaching the tubing to a dedicated portal on the sheath.*

Fig. 18 *When using continuous irrigation it is essential that continuous egress is made available by removing an obturator from a second port. This egress route should be dedicated for that purpose, separate from the main working port.*

conventional methods requiring multiple joint fixation. Pneumatic and electronic systems have avoided many of these historically cumbersome formats. The anticipated procedure length, the surgical goal, and availability of skilled surgical assistants are most important in deciding on the use of a holder. For many common procedures such as ETV or septal fenestration, the actual surgery time can be as short as several minutes and the use of a holder is personally not appreciated. Similarly, longer procedures involving tumor management within the third ventricle are unforgiving with respect to any degree of drift and demand continuous manipulations of the scope making rigid fixation with a holder ill-advised.

Hemostasis

Some degree of intraventricular hemorrhage is inevitable with any intraventricular endoscopic procedure. Most hemorrhage is venous or choroidal in origin and will dissipate quickly with constant irrigation. When visualization is obscured to the point at which visualization is less than optimal, surgery is best temporarily postponed. In some situations of mild to moderate intraventricular hemorrhage it is more useful and less tiring to replace the endoscope with a standard ventricular catheter, repeatedly irrigate and drain with 5-10cc aliquots, then replace the endoscope once the CSF return has visibly cleared.

Other methods for achieving hemostatis are dependent upon the site of bleeding. Hemorrhage from choroid plexus is usually controlled with bipolar coagulation. Similarly, focal sites of venous hemorrhage if identified can be controlled with bipolar coagulation. Identification of bleeding sites is made simpler by approaching the site and applying direct irrigation rather than withdrawing away from the source. Balloon tamponade for several minutes with a 3 Fr embolectomy catheter is another effective method of achieving hemostasis when bleeding does not readily cease with irrigation or coagulation. In the rare event of an arterial injury it is recommended that the endoscope be replaced with a ventricular drain and an emergent cerebral arteriogram with possible interventional therapy be performed.

Wound Closure

An important aspect of wound closure includes isolating the intraventricular CSF from the subarachnid space. The cortical incision should be sealed by placing hemostatic agents such as thrombin-soaked gelatin sponge within the proximal most aspect of the endoscopic path and below the cortical surface. It is essential that this be placed well into the subcortical region to avoid spontaneous expulsion and CSF efflux into the subdural or extracranial space (Fig. 19). Subdural hygromas and CSF wound leaks are nearly

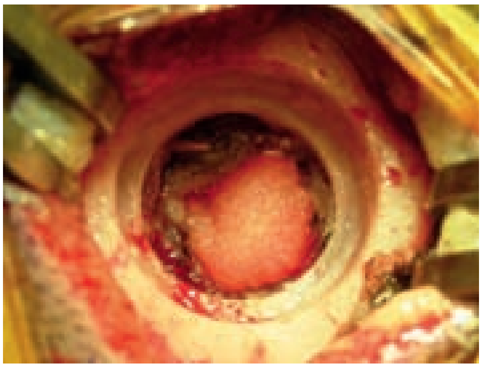


Fig. 19 *Throbmin soaked gelatin sponge is a very effective method for occluding the endoscopic path and reducing the potential for CSF to escape from the ventricular compartment. It is important to imbed the material within the subcortical area to prevent spontaneous expulsion.*

Fig. 21 *This photograph is from a patient who underwent a right frontal endoscopic colloid cyst removal one week prior. The incision was placed just behind the hairline and forward scalp retraction was used to mask the entry site. The contour of the forehead is maintained flush with a titanium burr hold cover.*

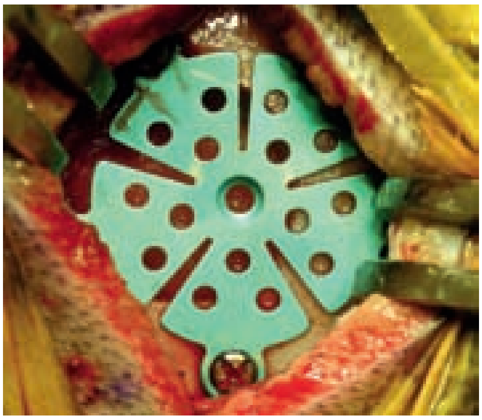


Fig. 20 *Titanium burr hole covers, preferred over autologous bone chips, provide a durable and smooth contour to the entry site.*

Fig. 22 *Shown is a patient who had a previous left frontal endoscopic removal of a third ventricular ependymoma. Given the receding hairline the incision was made within a forehead crease. A titanium burr hole cover with a detailed skin approximation yielded an excellent cosmetic result.*

eliminated using this technique. The use of autologous bone chips within the burr hole has been abandoned for a couple of reasons. First, settling and resorption of these fragments can result in a visible depression on the skin surface, which is most important with frontal that are positioned anterior to the hair line or on the forehead approaches (i.e. colloid cyst removal, pineal region approaches). Further, migration of these bone fragments into the ventricular compartment with ventricular outflow obstruction has been reported. For burr holes placed at or anterior to the hairline, a titanium burr hole cover is preferred for excellent cosmetic results (Figs. 20, 21, 22).

Ventricular Anatomy

General
Given the heavy reliance on intraventricular navigation, familiarity with the pertinent anatomy is essential to safe endoscopic neurosurgery. Knowledge of relevant anatomy is related to the contemplated procedure. The intraventricular anatomy surrounding the foramen of Monro and the internal third ventricle are of paramount importance to most intraventricular endoscopic procedures.

Lateral Ventricle
Pertinent anatomical landmarks near the foramen of Monro include the columns of the fornix, the choroid plexus, the septum pellucidum, and the head of the caudate nucleus (Figs. 23, 24, 25). The vascular tributaries that serve as important landmarks most notably include the septal vein and the thalamostriate vein. The former lies on the septal leaflet and crosses the column of the fornix at the posterior aspect of the foramen of Monro and drains into the internal cerebral vein. The thalamostriate vein, also draining into the internal cerebral vein, runs between the thalamus and the head of the caudate nucleus. These veins are quite variable with regard to their course and relationship to the ependymal surface.

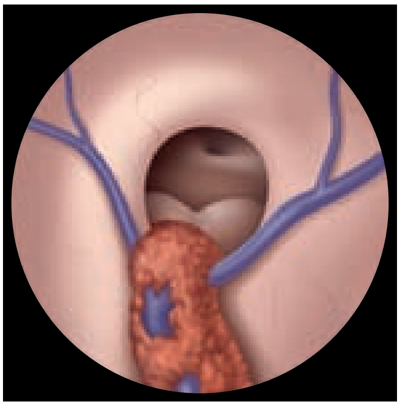


Fig. 23 *In this illustration of the right foramen of Monro the pertinent and most reliable anatomy includes the septal and thalamostriate veins, the choroid plexus, and the fornix. Through the foramen the paired mammillary bodies and the infundibular recess are recognized.*

Fig. 24 *This endoscopic image is obtained during endoscopic ventriculoscopy in a cadaver. The choroid plexus marks the posterior aspect of the foramen of Monro. The anterior and medial margin of the foramen are limited by the fornix.*

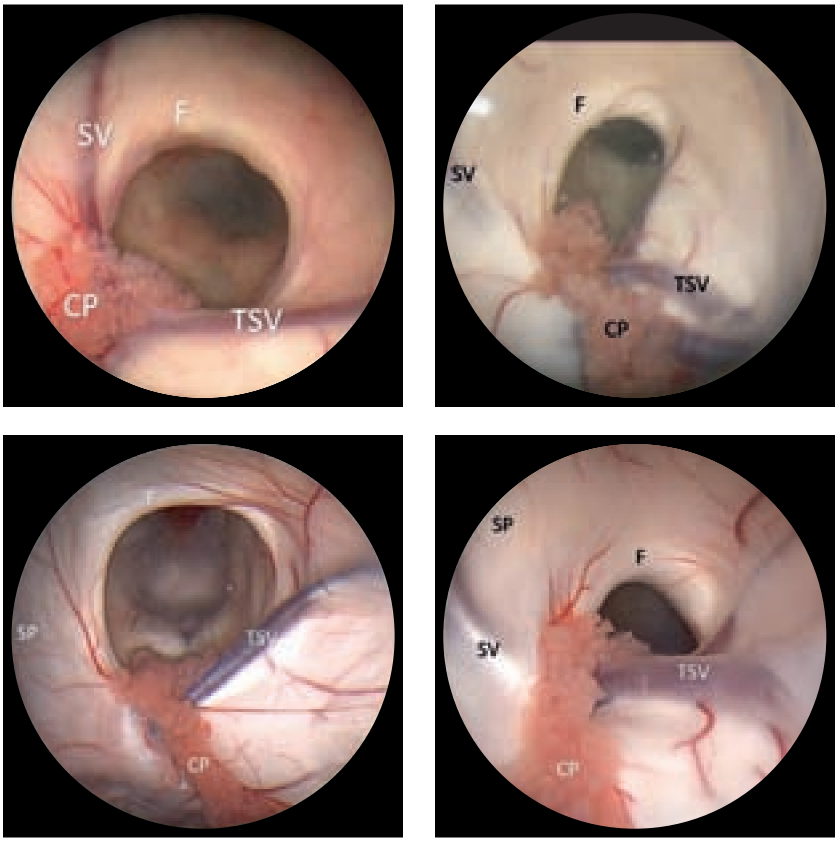


Fig. 25 *Endoscopic images of the right foramen of Monro are shown. The pertinent anatomy includes the fornix (F), the septal vein (SV), the thalamostriate vein (TSV), the choroid plexus (CP), and the septum pellucidum (SP).*

Orientation is most reliably obtained through recognition of the choroid plexus. The choroid serves as a nearly infallible reference in an anterior-posterior plane. The choroid plexus angles laterally away from the posterior aspect of the foramen. Since no choroid plexus exists anterior to the foramen of Monro, the absence of such upon initial ventricular inspection implies that a more posterior direction is needed to approach the foramen. Alternatively, if choroid is seen traversing the entire field of view, the correct maneuver is to direct the scope more anterior.

Orientation is also facilitated by the venous anatomy. In general smaller caliber venous tributaries are found further away from the foramen (regional veins all converge into the internal cerebral veins via the thalamostriate and septal viens). These structures although having some variability serve as one of the most important landmarks for navigating within the anterior horn and body of the lateral ventricle.

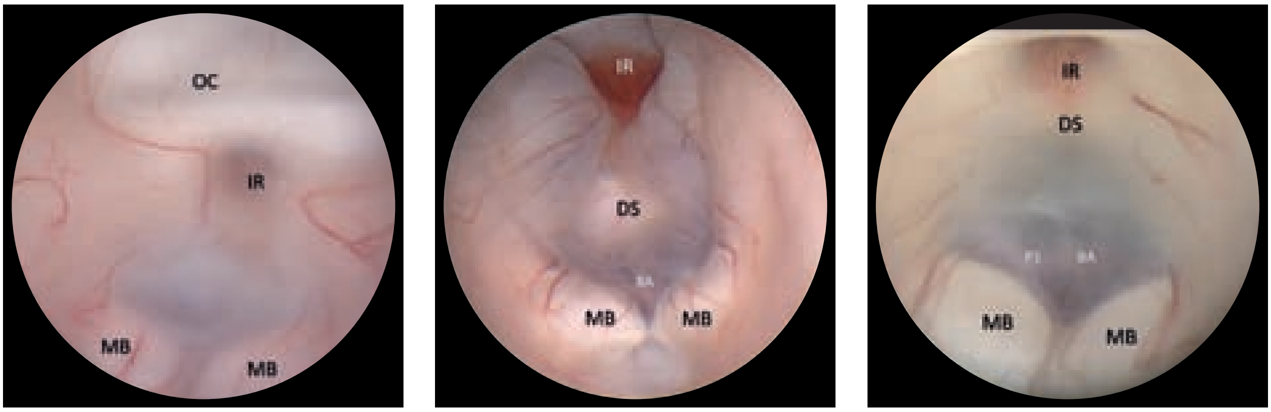
The superior and anterior border of the foramen of Monro is defined by the body and column of the fornix. The dimension of the foramen is variable and dependent upon the degree and duration of the hydrocephalus. On the medial aspect of this exposure is the septum pellucidum, frequently being attenuated and fenestrated in long standing hydrocephalus.

Third Ventricle

With respect to the pertinent anatomy of the inferior third ventricle, it is essential that the neurosurgeon be familiar with the following landmarks: the anterior commissure, the lamina terminalis, the optic chiasm, the infundibular recess, the tuber cinereum, the mammillary bodies and the adytum of the aqueduct (Figs. 26, 27, 28). These anatomical landmarks differ significantly and are less constant than the anatomy seen in the region of the foramen of Monro. Although not part of the third ventricle, the dorsum is a very important landmark between the infundibular recess and mammillary bodies. Predicable anatomical landmarks in the posterior aspect of the third ventricle are of great importance if performing surgery on pineal region and posterior third ventricular tumors. From a superior to inferior direction, these include the choroid plexus and the tela choroidea on the roof of the third ventricle, the paired internal cerebral veins, the habenular commissure, the pineal recess, the posterior commissure, and the adytum of the aqueduct (Figs. 29–31).

Fig. 26 *An endoscopic view of the third ventricular floor in a cadaver demonstrates important anatomical landmarks.*

Fig. 27 *This illustration of the floor of the third ventricle highlights important landmarks including the optic chiasm, the infundibular recess, the dorsum sella, the basilar apex, and the mammillary bodies.*



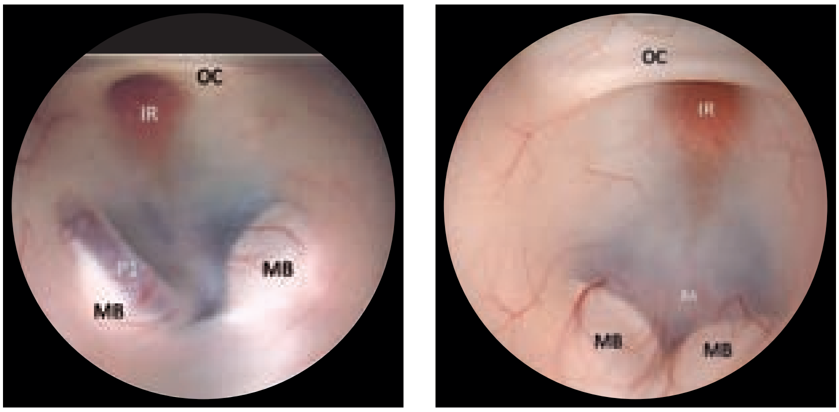


Fig. 28 *Endoscopic images of the third ventricle are shown. The pertinent anatomy includes the optic chiasm (OC), infundibular recess (IR), dorsum sella (DS), mammillary bodies (MB), basilar apex (BA), and the P1 division of the posterior cerebal artery (P1).*

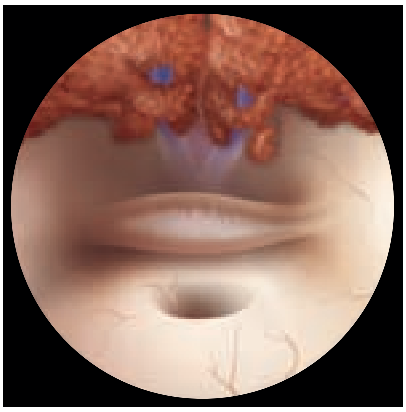


Fig. 29 *An illustration of the posterior third ventricle demonstrates the choroid plexus and tela chroidea of the roof of the third ventricle, the habenular commissure, the pineal recess, the posterior commissure, and the aqueduct.*

Fig. 30 *This endoscpic view into the posterior third ventricle of a cadaver illustrates the choroid plexus and the internal cerebral veins on the roof of the third ventricle. The habenular and posterior commissures border the pineal recess. The aqueduct is located immediately anterior to the posterior commissure.*

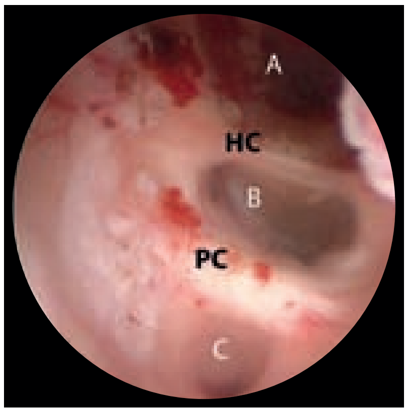


Fig. 31 *Endoscopic view into the third ventricle after endoscopic removal of a third ventricular brain tumor. The tela choroidea of the third ventricle (A), the pineal recess (B), and the aqueduct of Sylvius (C) are clearly seen. The habenular commissure (HC) and posterior commissure (PC) are white matter tracts that separate these landmarks.*

Hydrocephalus

The use of endoscopic surgery has positively impacted the patient with noncommunicating or compartmentalized hydrocephalus. In fact, comprehensive and contemporary management of patients with hydrocephalus is no longer feasible without the integration of endoscopic surgery. The benefit gained by eliminating ventriculoperitoneal shunts through endoscopic third ventriculostomy (ETV) or aqueductoplasty needs no elaboration. Similarly, reduction of shunt burden can be achieved through fenestration of the septum pellucidum or intraventricular cysts. Thus, the endoscopic goal when treating hydrocephalus should always be to eliminate or reduce the need for implanted hardware for CSF diversion.

Endoscopic Third Ventriculostomy (ETV)

Patient Selection

It is without debate that ETV serves as the treatment of choice in many cases of noncommunicating hydrocephalus with the success being dependent on many variables (Table 1). The patients considered to be optimal candidates are those with acquired forms of noncommunicating hydrocephalus when the site of obstruction resides anywhere from the back of the third ventricle downstream to the outlet of the fourth ventricle. Ideal candidates for ETV have hydrocephalus secondary to pathologic entities that include mesencephalic tumors (tectal gliomas), aqueductal stenosis, and 4th ventricular outlet obstruction (Fig. 32). While many variables have been evaluated that may impact the success of ETV, most would agree that patient age less than 6-12 months and an infectious etiology are probable negative prognostic indicators. However, while a young age may predict a decreased potential for ETV function in otherwise appropriate candidates, the alternative of

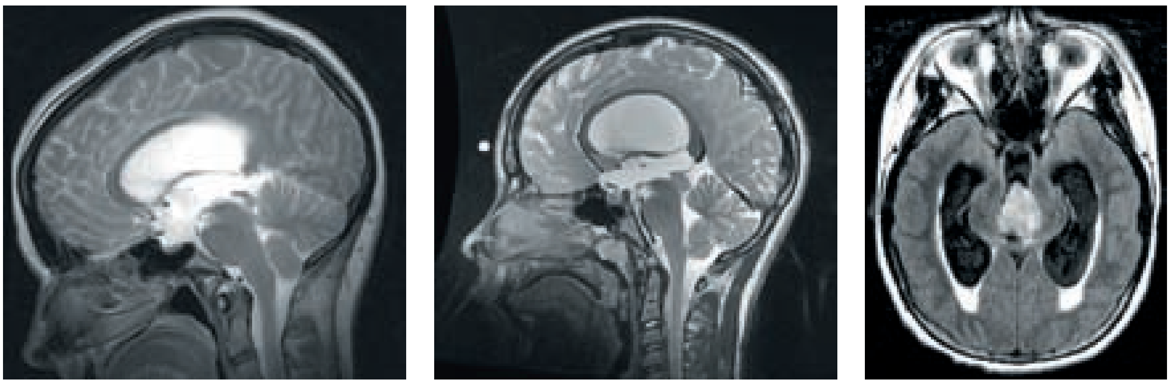


Fig. 32 *Various forms of noncommunicating hydrocephalus that are ideal candidates for CSF diversion by ETV.: aqueductal stenosis (left); tectal glioma (middle); pineal region tumor (right).*

ETV Success rates	Features
Excellent (80-100%)	Acquired aqueductal stenosis Mesencephalic/tectal glioma Benign pineal region tumor/cysts 4th ventricular outlet obstruction
Moderate (50-75%)	Shunt-dependent hydrocephalus (myelodysplasia, aqueductal stenosis, etc.) 4th ventricular tumors Brain stem gliomas Chiari Type I malformation/hydrocephalus
Poor (< 50%)	Age < 6-12 months Post-infectious hydrocephalus (meningitis, ventriculitis) Disseminated malignant tumors

Table 1 *Estimation of ETV Success Based on Patient Selection*

shunting is not necessarily a more appealing long-term solution given the high failure rate of ventriculoperitoneal shunts in infants.

Preoperative imaging should always be used to confirm noncommicating hydrocephalus. MRI can provide some important information in patient selection. In equivocal cases of aqueductal stenosis based on standard MRI sequences flow-sensitive sequences (CINE, 2-D phase contrast) can be revealing. Late onset aqueductal stenosis or fourth ventricular outlet obstruction can masquerade as normal pressure hydrocephalus (NPH). This distinction again is better appreciated with high resolution T2-weighted sequences (constructive interference of steady state (CISS)) or the aforementioned motion-sensitive sequences (Figs. 33,34).

Fig. 33 *High resolution (FIESTA sequence) of the cerebral aqueduct clearly indicating a short segment stenosis as the cause of noncommunicating hydrocephalus.*

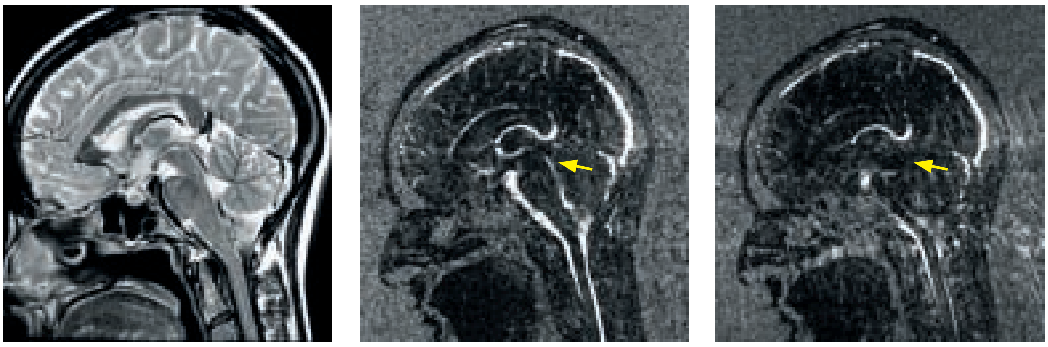


Fig. 34 *T2-weigheted MRI and corresponding phase contrast (CINE) sequences demonstrating bidirectional flow (white to black) through the aqueduct (arrow).*

Preoperative MRI is useful to assess anatomical features that may contribute toward the success of the procedure or modify the surgical technique. The relative size of the foramina of Monro, the position of the basilar apex, and the prepontine subarachnoid space can be integrated into the surgical planning. Although some have advocated that ETV be avoided in patients with a diminished prepontine interval (PPI) safe fenestration can be performed (Fig. 35). Other details that may alter the surgical plan with respect to entry site laterality include an eccentric position of the basilar apex or significant asymmetry of the foramina of Monro.

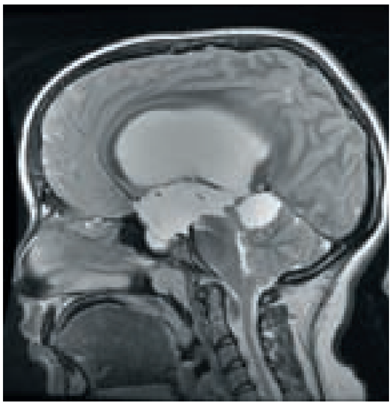


Fig. 35 *Sagittal T2-weighted MRI in a patient with aqueductal stenosis with severe ventriculomegaly demonstrates a diminished prepontine interval (PPI). A ventricular diverticulum is noted in the posterior fossa.*

Surgical Technique

The basis of successful ETV relies on the creation of a fenestration that allows intraventricular CSF to freely flow into the subarachnoid space where normal resorptive potential exists. The technique of performing an ETV is relatively standard. Basic principles include selecting an optimal site of entry, cannulating the frontal horn of the lateral ventricle, navigation through the foramen of Monro, and perforation of the tuber cinereum. With respect to the entry site, a burr hole is typically placed 1 cm anterior to the coronal suture and 2–3 cm off the sagittal midline. This entry site will vary depending on the relative position of the foramen of Monro and the prepontine subarachnoid space. The pre-operative sagittal MRI is a very useful for determining this trajectory and entry site (Fig. 36). Typically, navigational guidance is not required for ETV. In patients with a reduced prepontine interval however stereotactic guidance is preferred in order to select a trajectory that parallels the upper aspect of the clivus. This assures a trajectory that will avoid any angling of instruments toward the brain stem and basilar trunk once below the floor of the third ventricle.

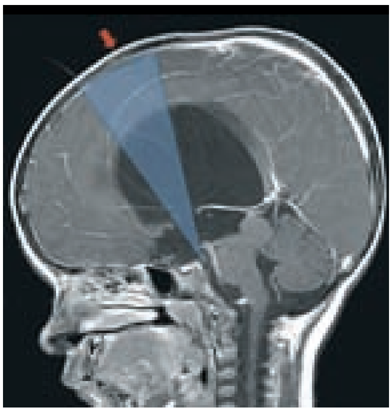


Fig. 36 *Sagittal T1-weigthed MRI is shown with a range of acceptable trajectories that pass through the foramen of Monro and target the prepontine cistern. The coronal suture is identified by the red arrow.*

In most patients who have significant ventriculomegaly cannulating the frontal horn of the lateral ventricle is relatively straightforward. In patients with smaller ventricular size or altered ventricular shape (cavum spetum pellucidum, mutlicompartmentalized hydrocephalus), navigational guidance is recommended. It is also suggested that in such situations with altered or small ventricular compartments, a ventricular catheter should be used to precede the endoscope or endoscopic sheath given its smaller diameter. This catheter is used as a sounding needle through which gentle ventricular insufflations can be used. It is routinely suggested that a right frontal approach be utilized unless appreciable ventricular asymmetry exists that favors a left frontal approach.

Once the frontal horn of the lateral ventricle has been accessed, continuous irrigation is typically utilized to maintain a clear visual field and reduce the risk of ventricular collapse through CSF egress. With continuous irrigation it is mandatory that a patent egress channel be used in order to avoid raised intraventricular pressure. The endoscope is navigated through the foramen of Monro, into the third ventricle. Once the endoscope is navigated into the third ventricle it is necessary to identify the relevant anatomy (Figs. 26–28). While many had advocated that the fenestration be performed in the midline at some predetermined distance between the infundibular recess and the mamillary bodies, it has become increasingly apparent that a midway point is not always reliable. While it is nearly always the case that the fenestration be performed in the sagittal midline, the anterior-posterior site of fenestration will vary depending on the position of the dorsum sella relative to the basilar artery. Essentially, the safest entry will be directly behind the dorsum sella to prevent any inadvertent injury to the basilar apex or its tributaries. Thus, the dorsum sella whether visualized or found by gentle probing, is the most reliable landmark for finding the prepontine space.

Variable techniques are utilized for the initial perforation including blunt perforation, sharp dissection, bipolar coagulation, and laser. It is generally preferred that an atraumatic blunt perforation be utilized under continuous observation. It is also important that the perforation encompass both the tuber cinereum and the underlying membrane of Liliequist. This membrane is apparent as a separate structure and should not be mistaken as scarring of the subarachnoid space. Once the blunt perforation is performed, the

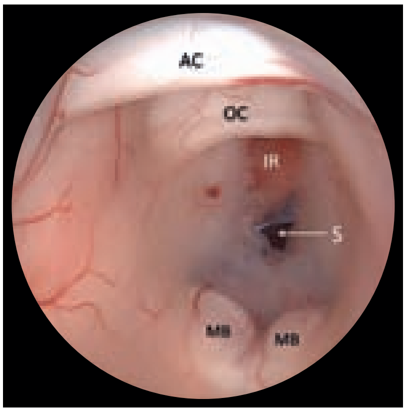


Fig. 37 *An endoscopic view from the foramen of Monro illustrates the stoma (S) of the ETV with its relative position to the anterior commissure (AC), optic chiasm (OC), infundibular recess (IR), and the mammillary bodies (MB).*

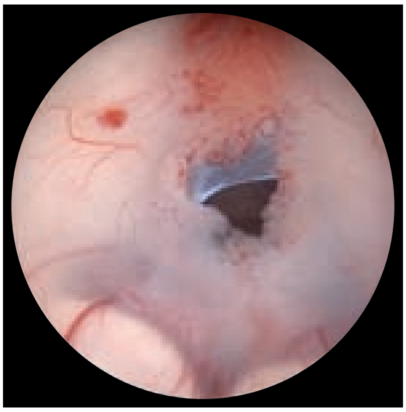


Fig. 38 *The membrane of Liliequist is seen immediately beneath the floor of the 3rd ventricle. The fenestration has been created in both to insure unobstructed flow.*

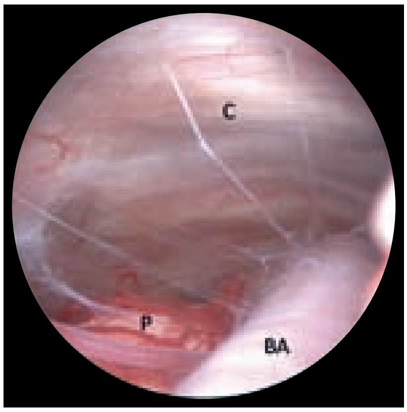


Fig. 39 *Endoscopic view after fenestration of the tuber cinereum should reveal a clear prepontine space. The basilar artery (BA), the surface of the pons (P), and the dural surface of the clivus (C) are indicated.*

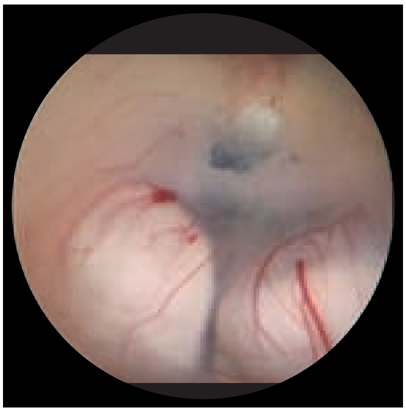


Fig. 40 *Endoscopic view at the time of ETV demonstrates an intact membrane of Liliequist after initial fenestration of the tuber cinereum.*

Fig. 41 *Sharp dissection was used to separately open this membrane thus achieving unobstructed flow into the subarachnoid space of the prepontine cistern.*

stoma is then increased in size by utilizing a saline filled #3-French embolectomy balloon catheter. Inflating the balloon within the subarachnoid space and pulling it into the third ventricle is strongly discouraged. Every attempt should be made to trap the balloon within the stoma and then utilize gradual dilatation. With deflation of the balloon clear visualization into the prepontine subarachnoid space should be apparent ensuring that both the floor of the third ventricle and the membrane of Liliequist have been adequately opened (Figs. 37–39). In rare situations Liliequist's membrane will require additional maneuvers including sharp dissection or cautery to enter the subarachnoid space (Figs. 40, 41). In situations where the prepontine cistern is negligible or absent, the fenestration of the tuber cinereum can be safely performed directly over the dorsum sella (Figs. 42, 43).

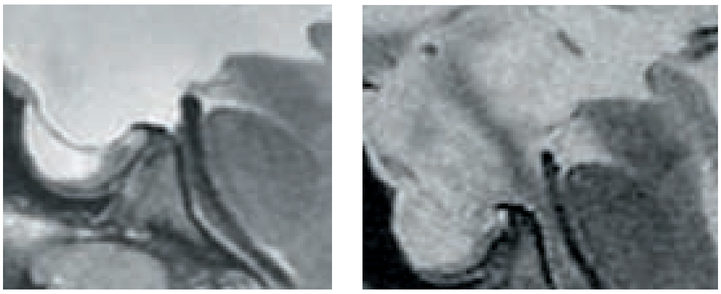


Fig. 42 *These sagittal T2-weighted MRI scans detail the obliterated prepontine in a patient with aqueductal stenosis. The successful flow across the tuber cinereum following ETV is appreciated by comparing the preoperative image (left) with the postoperative MRI (right).*

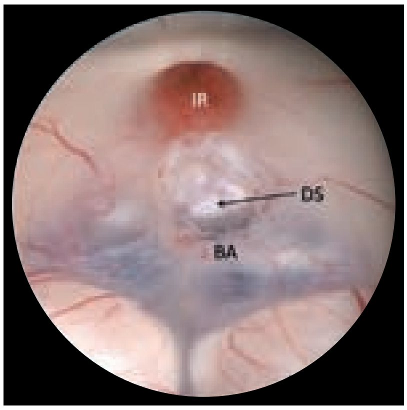


Fig. 43 *This endoscopic view demonstrates the site of fenestration in a patient with an absent prepontine subarachnoid space. The fenestration for the ETV was created directly on top of the dorsum sella (DS) to insure the greatest distance possible from the basilar artery (BA).*

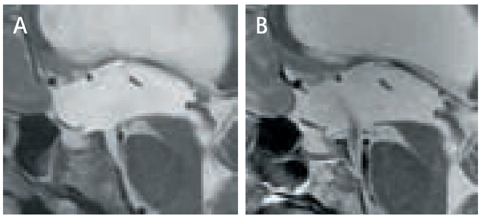


Fig. 44 *The expected turbulent flow seen at the site of the ETV is demonstrated in these sagittal T2-weighted MRI scans before (A) and after (B) surgery.*

While observation into the subarachnoid space insures a complete fenestration, one should avoid passing the endoscope into the prepontine cistern for anatomical tours. Adequate fenestration is usually indicated by pulsatile movements of the floor of the third ventricle consistent with a cardiac cycle. If any small areas of hemorrhage are recognized following the fenestration, it is best to avoid attempts to coagulate these areas, but instead utilize continuous irrigation and in some situations tamponade with the balloon catheter.

The use of externalized ventricular drainage (EVD) is debated, but for most patients undergoing elective endoscopic third ventriculostomy a drain is typically not warranted. EVD should be used in patients who present with obtundation and signs of acutely raised intracranial pressure.

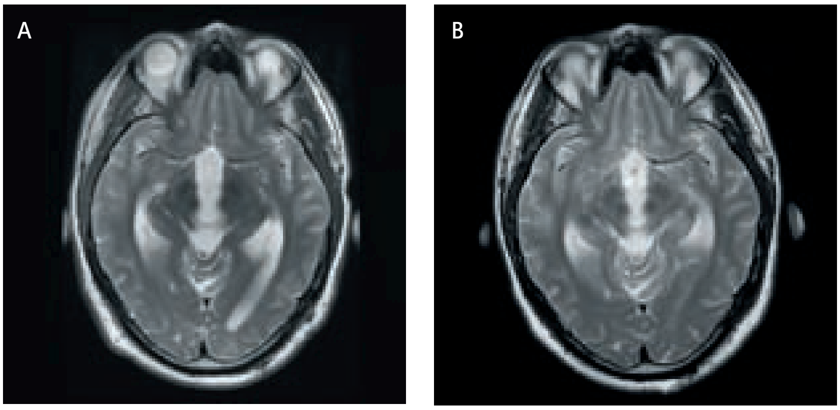


Fig. 45 *Axial T2-weighted MRI scans prior to (A) and after (B) ETV. The signal void in the anterior third ventricle indicates a patent stoma.*

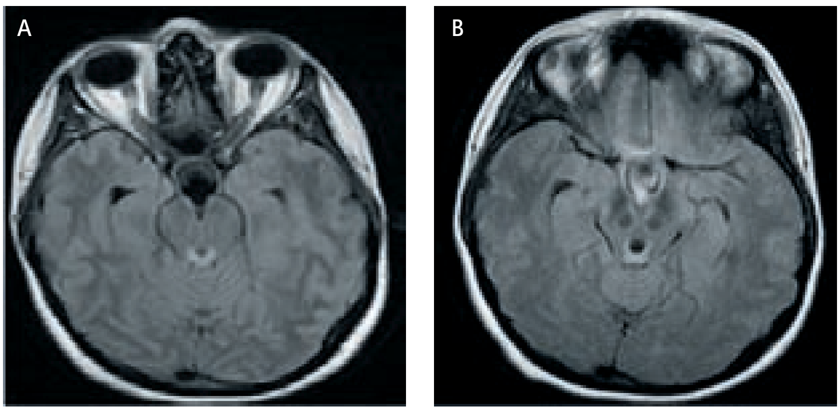


Fig. 46 *FLAIR-weighted MRI scans prior to (A) and after (B) ETV. The turbulent flow pattern in the anterior third ventricle indicates a patent stoma.*

Externalized monitoring is also used when the ETV is performed in the patient with shunt-dependent hydrocephalus and a low-complaint ventricular system. If EVD is used in previously shunted patients it is common to record pressures above a normal range for variable time periods even in light of a MRI-defined patent ETV and in patients without symptoms of raised intracranial pressures.

The resolution of clinical symptoms is the principle basis for assessing ETV success. An MRI scan performed in the acute postoperative time period serves as an excellent baseline investigation to establish patency of the stoma at the level of the floor of the third ventricle. This patency is easily established on standard sequences including T2 and FLAIR sequences in variable planes (Figs 44–46). Motion sensitive, 2D phase contrast (CINE) sequences have also been advocated as a measure of flow through an ETV stoma. A decrease in the ventricular size is not always appreciated in 2-dimensional assessment. However, other subtle signs of a functional ETV include elevation of the floor of the third ventricle, a reduction in the degree of transependymal signal change, and an increase in the subarachnoid space over the cerebral convexities.

Aqueductoplasty

Patient Selection

Aqueductoplasty has been advocated as an alternative to ETV for CSF diversion in patients with noncommunicating hydrocephalus secondary to aqueductal stenosis. Patients should only be considered if there is a short segment aqueductal stensosis. Thus, stenosis due to external compression or diffuse inflammatory changes would predictably have a higher rate of failure compared with stenosis due to a focal septation (Figs. 47, 48).

Fig. 47 *Sagittal T2-weighted MRI of a patient with a short segment aqueductal stenosis that would be considered a good candidate for endoscopic aqueductoplasty.*

Fig. 48 *This sagittal T2-weighted MRI illustrates a patient with a tectal glioma causing compression of the aqueduct along the majority of its length. This patient would not be expected to have lasting success from aqueductoplasty.*

Even in ideal candidates, the use of aqueductoplasty is generally not favored for several reasons. First, these same patients are typically excellent candidates for ETV. Compared with ETV, aqueductoplasty has been shown to have higher rates of re-occlusion and cranial neuropathy (cranial nerve III). Further, long term patency is dependent on the use of stents across the site of aqueductoplasty. Thus, given the higher rate of neurological morbidity, reliance on stents and frequent re-occlusion seen with aqueductoplasty, ETV is preferred for treating noncommunicating hydrocephalus secondary to aqueductal occlusion. Aqueductoplasty is advocated in patients with isolated fourth ventricle after successful shunting of the supratentorial compartment.

Surgical Technique

Because the vertical orientation of the aqueduct is difficult to recapitulate with a solid lens endoscope, any attempt to perform aqueductoplasty must compensate with a far anterior entry site (4–6 cm anterior to the coronal suture). The best approximation for an entry site is obtained by drawing a line from the cranial surface that passes thorough the foramen of Monro into the rostral aqueduct. Even with that modification, flexible instruments (balloon catheters) are usually needed to pass blindly through the site of obstruction. Steerable fiberoptic systems are an appealing alternative to a rigid endoscope and hence are preferred for performing safe endoscopic aqueductoplasty. Once the proximal aqueduct is visualized, the fenestration should proceed in a manner similar to ETV (Fig. 49). Balloon dilatation should proceed with caution given the proximity of the 3rd cranial nerve nuclei. Confirmation of a successful fenestration relies on visualizing the rostral 4th ventricle including the choroid plexus and superior medullary velum (Fig. 50). Due to the propensity for re-occlusion, stents across the site are advocated. However, this practice conflicts with the intent to avoid implanted hardware and also favors ETV as an alternative.

In patients with an isolated or "trapped" fourth ventricle with a functional shunt in the lateral ventricle, endoscopic aqueductoplasty is a useful means for avoiding a posterior fossa cystoperitoenal shunt. In this situation, the area of stenosis is best approached from an infratentorial trans-fourth ventricular direction. This approach through the fourth ventricle towards the aqueduct is preferred since the supratentorial ventricular system is typically collapsed making endoscopic navigation difficult and potentially dangerous. Given the underlying infalmmatory etiology of compartmentalized hydrocephalus, these patients are at high risk of re-occlusion of the aqueductoplasty if stenting is not used.

Fig. 49 *This image shows an endoscopic view in a cadaver of the proximal aqueduct with the posterior commissure immediately above.*

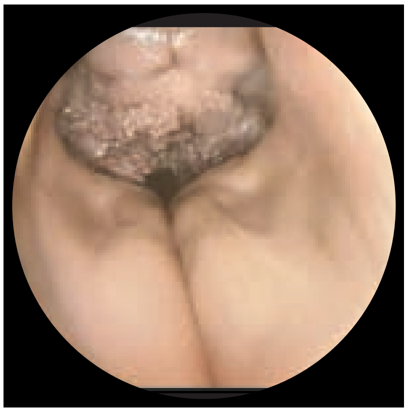


Fig. 50 *Endoscopic view into the fourth ventricle from a transaqueductal approach is demonstrated in a cadaver. At the top of the image is the roof of the fourth ventricle with choroid plexus. The bottom aspect of the image shows the floor of the fourth ventricle (i.e. median sulcus, sulcus limitans, facial colliculi, etc.) limited on either side by the cerebellar peduncles.*

Choroid Plexus Fulguration

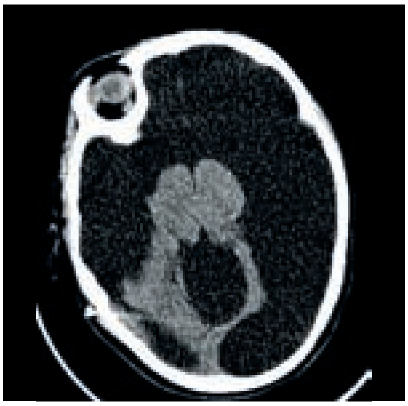


Fig. 51 *This CT scan is from an infant with hydranencephaly. Clearly shown is the lack of any overlying cortical mantle and a normally developed diencephalon.*

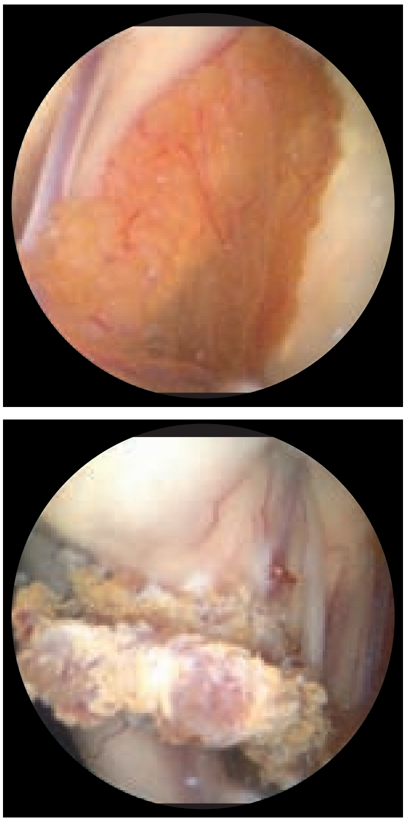


Fig. 52 *Enodscopic views of the choroid plexus from the patient shown in the preceding CT illustrate the choroid plexus before (top) and after (bottom) bipolar electrocautery.*

Patient Selection

Choroid plexectomy has been advocated well before the era of neuroendoscopy. Enthusiasm for the technique waned because of significant morbidity and poor efficacy. The fact that choroid plexus is present in all the ventricular compartments, as well as the recognition of extra-choroidal sources of CSF production partly explain why plexectomy alone is seldom able to adequately control hydrocephalus. With the advent of neuroendoscopic methods, the morbidity has been substantially reduced and recent work has shown some limited utility under specific conditions. One indication in which choroid plexectomy has been shown to be a valid alternative to shunting is in children with hydranencephaly and communicating hydrocephalus with repeated shunt malfunctions (Fig. 51).

Surgical Technique

It is important in cannulating the ventricular compartment of individuals with such large CSF compartments, that the light source be adjusted to maximal intensity. A coronal or occipital approach can be used and is dependent upon the degree of ventriculomegaly and ventricular morphology. In patients with hydranencephaly, a coronal approach is usually adequate. In the absence of hydranencephaly bilateral occipital burr holes are needed to ensure access into the bodies and temporal horns on either side. Steerable fiberoptic endoscopes can offer some advantage in reaching plexus beyond that of the body of the lateral ventricle (i.e. temporal horns, third ventricle). In patients with extreme ventriculomegaly there is minimal cortical or subcortical tissue at risk from wide excursions of the endoscope and the mobilization of the endoscope within the ventricular compartment is easily accomplished. Unipolar or bipolar coagulation is generously used to fulgurate the choroid plexus (Figs. 52). The coagulation device can be used to push or retract the choroid away from ependymal surfaces or veins prior to applying current. Continuous irrigation with lactated Ringers solution and an open egress port minimizes any potential for thermal injury.

Septal Fenestration

Patient Selection

Endoscopic fenestration of the septum pellucidum is one of the simplest intraventricular endoscopic procedures. This procedure, when combined with a unilateral ventriculoperitoneal shunt or as primary treatment for unilateral loculated ventriculomegaly is an excellent technique for reducing shunt burden. Thus patients with obstruction at both foramina of Monro, typically by way of third ventricular or large suprasellar brain tumors are excellent candidates (Figs. 53,54). Other excellent candidates are those who develop loculated ventriculomegaly after shunt placement (Fig. 55).

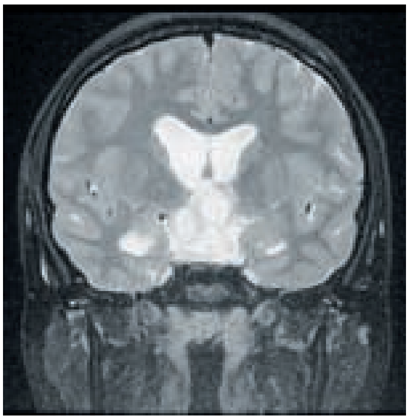


Fig. 53 *This sagittal T2-weighted image on a patient with a suprasellar germ cell tumor demonstrates an excellent candidate for unilateral shunt placement with an endoscopic septal fenestration.*

Fig. 54 *This patient with a low grade tumor for the forniceal region was treated with simultaneous endoscopic septostomy and insertion of a unilateral shunt.*

Fig. 55 *This patient that developed unilateral ventriculomegaly 1 year after placement of a right sided shunt was treated with an endoscopic septal fenestration.*

Surgical Technique

The technique of endoscopic septal fenestration begins with an entry site that uses a trajectory as perpendicular as possible with reference with septum pellucidum. Thus, compared with an ETV a lateral entry is beneficial. An entry site approximately 5 cm off the midline near the coronal suture is typical when using a frontal approach. This lateral displacement is limited by the Sylvian fissue and vascular tributaries emanating from this region. Once the lateral ventricle is accessed, a site within the septum pellucidum is selected with the following principles. First, an avascular site should be chosen. Although the septal vein can be sacrificed this is seldom necessary and runs the risk of hemorrhage with subsequent visual obscuration. Thus, it is recommended that larger venous tributaries not be included in the fenestration. The stoma should be high enough on the septum pellucidum to avoid injury to the underlying body or column of the fornix. Additionally, a fenestration site higher on the septum will also minimize the risk of inadvertent injury to the contralateral fornix or thalamus. In an effort to minimize injury to the contralateral fornix or thalamus a parietal approach through the atrium is an excellent alternative trajectory (Fig. 56). This approach also offers the potential of creating large longitudinal fenestrations in the septum with minimal scope torque (Fig. 57). If a parietal approach is used, navigational guidance is recommended. When performing endoscopic septal fenestrations large openings (>1cm) or multiple openings should be

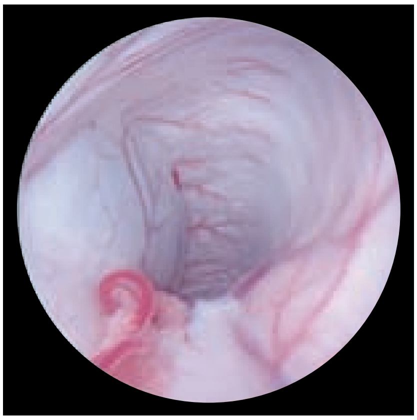


Fig. 56 *An endoscopic view of the septum pellucidum from a parietal approach demonstrates the large and relatively avascular portion of the septal region. The typical striated appearance of the corpus callosum is seen superiorly. The image also demonstrates how the trajectory minimizes potential trauma to the fornices.*

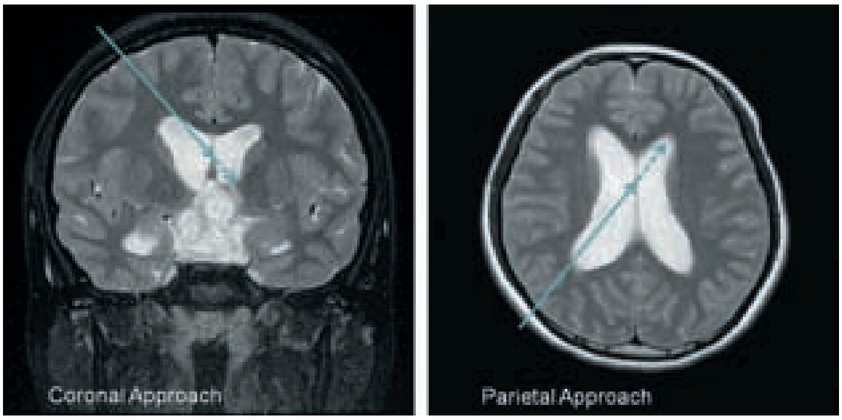


Fig. 57 *The comparison between a frontal (left) and parietal (right) approach to endoscopic fenestration is shown. The parietal approach for septal fenestration has several advantages including a direct rather than tangential approach into the septum pellucidum, a less restricted space beyond the fenestration, a relatively avascular area of the septum, and the potential for creating longer fenestrations in the septum.*

the goal so as to avoid delayed occlusion. It is vital that entrance into the contralateral ventricle be confirmed by the recognition of ependymal veins or choroid plexus within the contralateral ventricle. Since the septum derives from two separate leaflets the space between them can be mistaken as a ventricular compartment, thus resulting in an incomplete interventricular communication.

Intracranial Cysts

Septal Cysts

Patient Selection

Cystic variants of the septum pellucidum including cavum septi pellucidi (CSP), cavum vergae (CV), and cyst of the vellum interpositum are all amenable to endoscopic fenestration. The cysts of the septum commonly coexist as a CSP/CV complex. These cysts are infrequently symptomatic and disciplined patient selection should be employed to avoid unnecessary surgery. Most symptomatic patients present with signs of raised intracranial pressure from noncommunicating hydrocephalus due to obstruction of the foramina of Monro.

Surgical Technique

In symptomatic patients, fenestration of the ventricle into the cyst (ventriculocystomy) or from the cyst into the ventricle (cystoventriculostomy) is possible in most since the intraventricular CSF pathways are usually patent. Either an atrial or frontal approach can be used. The principles and techniques for fenestration are similar to that described for endoscopic fenestration of the septum pellucidum. It is preferred to fenestrate both leaflets of the midline cysts thus creating two separate stomata (Fig. 58). As in endoscopic septal fenestration, navigational guidance should be used to avoid misdirected trajectories if an atrial approach is selected.

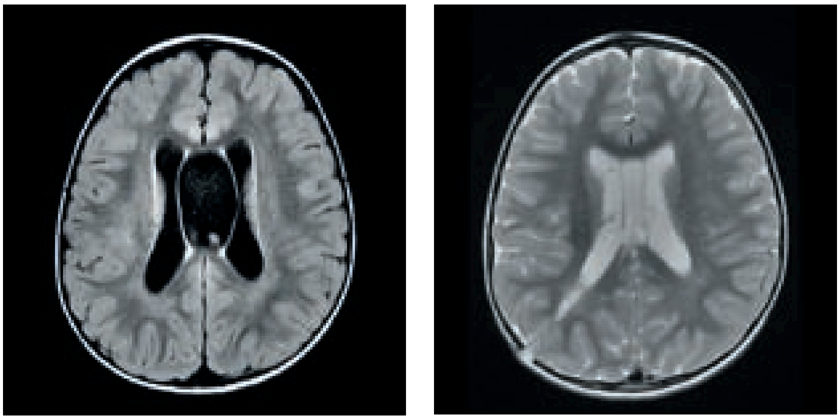


Fig. 58 *These MR images are obtained from a patient with a symptomatic cyst of the septum prior (left) and after (right) a right parietal endoscopic fenestration. The dual sites of fenestration on either septal leaflet are apparent. The postoperative image also demonstrates the return of the septal leaflets to a parallel orientation confirming decompression.*

Arachnoid Cysts

Patient Selection

Intracranial arachnoid cysts are common but rarely symptomatic. Therefore, patient selection needs to be disciplined. Once decided that an intracranial arachnoid cyst is symptomatic, the treatment options are variable including microsurgical cyst fenestration, cystoperitoneal shunting, and endoscopic fenestration. The role of endoscopic fenestration is limited to those cysts in which a communication can be created between the cyst and a normal CSF containing compartment including the ventricular compartment (cystoventriculostomy) or the subarachnoid space (cystocisternostomy). For cysts that do not approximate a cistern or ventricle, such as those overlying the convexity, endoscopic fenestration does not serve as a viable option.

Middle fossa arachnoid cysts, being the most common, can be successfully treated with endoscopic fenestration but enthusiasm for this procedure is somewhat tempered. The fenestrations achieved using purely endoscopic approaches are typically smaller in dimension compared with those achieved with microsurgical techniques. However, a purely endoscopic approach does offer the benefit of avoiding cyst evacuation and the inherent potential for subdural collections that can complicate microsurgical treatment (Fig. 59).

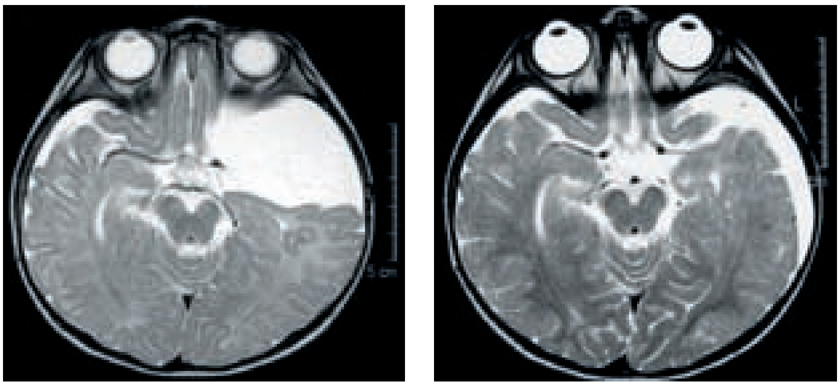


Fig. 59 *These MR images demonstrate a middle fossa arachnoid cyst prior (left) and 8 months after (right) a purely endoscopic fenestration in an infant who presented with divergent macrocephaly.*

Prepontine (suprasellar) arachnoid cysts have shown excellent response rates following endoscopic fenestration (Fig. 60). These cysts typically present with noncommunicating hydrocephalus from third ventricular obstruction.

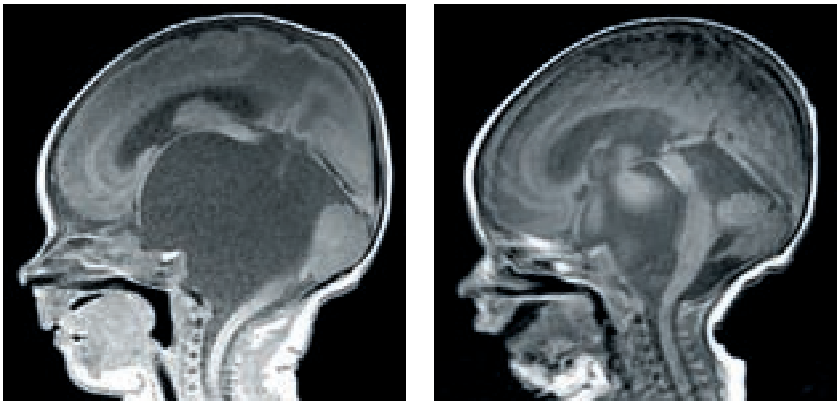


Fig. 60 *Sagittal T1 MRI images are shown from a patient with a prepontine (suprasellar) before (left) and after (right) endoscopic fenestration.*

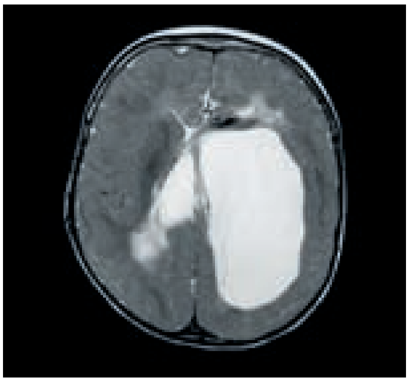


Fig. 61 *This patient previously treated with a right sided ventriculoperitoneal shunt is a good candidate for an endoscopic cystoventriculostomy as a means of avoiding biventricular shunting.*

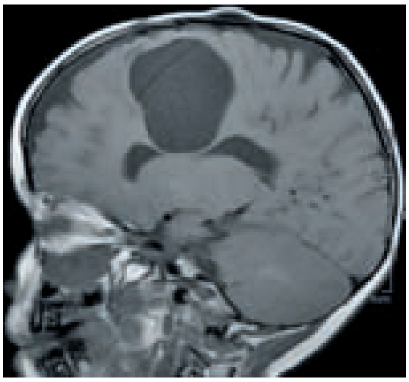


Fig. 62 *This patient with an encephaloclastic cyst from intrathecal chemotherapy was successfully treated with an endoscopic cystoventriculostomy.*

Fig. 63 *This right sided neuro-epithelial cyst is easily treated with a cystoventriculostomy given the approximation with the lateral ventricle.*

Variable types of cysts including encephaloclastic cysts, neuro-epithelial cysts, and compartmentalized hydrocephalus are frequently treated with simple endoscopic fenestration (Figs. 61–63).

Surgical Technique

When treating cysts with endoscopic fenestration, it is important that the dimensions of the fenestrations be large enough to successfully maintain a flow of CSF between the cyst and the opposing CSF structure. Cystocisternostomies for middle fossa arachnoid cysts are performed on the medial aspect of the cysts into the suprasellar, interpeduncular, and chiasmatic cis-

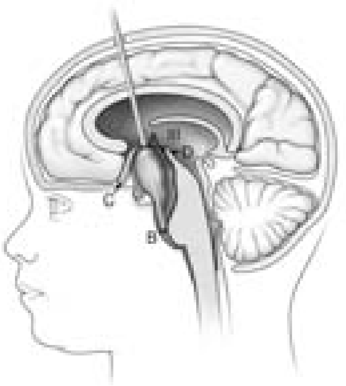


Fig. 65 *This diagram shows the typical trajectory used to perform an endoscopic fenestration of a prepontine (suprasellar) arachnoid cyst. Fenestrations are made at the (A) apical and (B) basal aspects of the cyst. These cysts commonly cause compression of the optic nerves (C) and the floor of the third ventricle (D).*

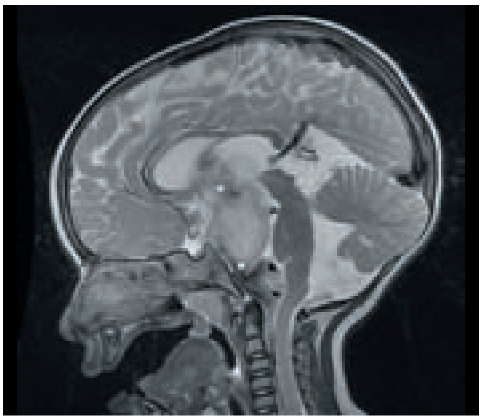


Fig. 66 *This sagittal MRI shows turbulent flow indicating the patent stomata following endoscopic fenestration of a prepontine arachnoid cyst. Fenestrations (*) have been created on the apical (ventriculocystostomy) and the basal (cystocisternostomy) aspects of the cyst.*

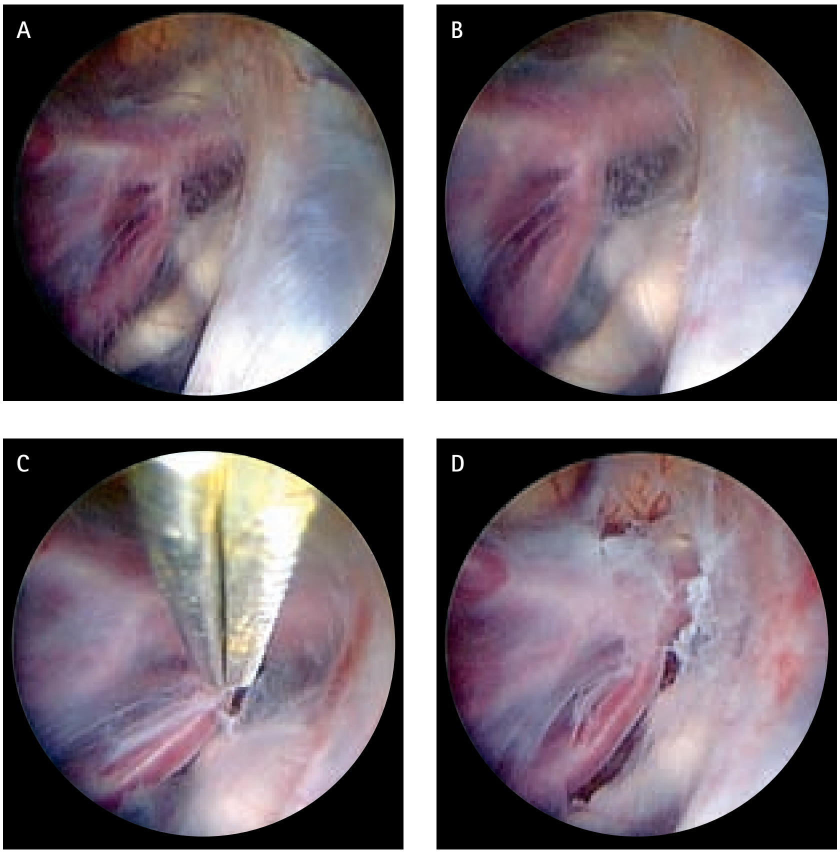


Fig. 64 *This series of operative images demonstrates the anatomy and technique of a purely endoscopic fenestration of a right middle fossa arachnoid cyst. The initial endoscopic view (A) affords clear identification of structures medial to the tentorial edge and within the basal cisterns. A closer view (B) shows the third cranial nerve passing lateral to the posterior clinoid process and the carotid artery with the posterior communicating and anterior choroidal arteries. Sharp dissection is used to pull and cut the arachnoid membrane (C) thus creating large fenestrations into the medial cisterns (D).*

terns. Sites of semitransparent arachnoid membrane are selected between the surrounding cranial nerves and arterial tributaries. Sharp dissection with scissors is preferred over electrocautery and laser given the proximity of neural and vascular structures (Fig 64). A bimanual technique whereby the membrane is elevated and then cut is advantageous if a biportal sheath is used. Prepontine arachnoid cysts are easily approached through a standard coronal approach (Fig. 65). Dual fenestrations including a ventriulocystomy on the apical aspect of the cyst and a cystocisternotomy on the basal aspect are performed to ensure that that subarachnoid flow is achieved in the event of persistent aqueductal occlusion (Fig. 66).

Brain Tumors

Colloid Cysts

Patient Selection

The colloid cyst of the third ventricle is an ideal tumor for endoscopic removal. This appeal is principally governed by the cystic nature of the mass. The deep central location within the ventricular compartment, along with the associated complexity of standard microsurgical removal further enhances the desire for endoscopic management. Careful patient selection is critical given the frequency with which asymptomatic patients are diagnosed. Rationales for surgical intervention appropriately include symptoms of raised intracranial pressure, ventriculomegaly in the absence of symptoms and radiographic evidence of progression (ventricular size or tumor mass). Less defined indicators include prophylaxis against clinical progression or sudden death and young age at the time of diagnosis. The ability to predict clinical progression is poorly defined. The natural history is not clear but is estimated that clinical or radiographic progression occurs in about 8% of patients over 10 years. The expectation of progression during a patient's lifetime is thus greater for younger patients. Variables that may precede clinical deterioration are ventriculomegaly, chronic headache and cyst size (> 1 cm diameter). Offering surgery to avoid the possibility of rapid deterioration must be balanced by a true estimation of operative risk to the patient, bearing in mind that many asymptomatic patients will have normal sized ventricles.

Surgical Technique

It is strongly advised that familiarity and experience be obtained with intraventricular endoscopic surgery prior to treating colloid cysts or other intraventricular tumors. Pre-operative intravenous corticosteroids are adminisgtered to reduce the potential risk of chemical ventriculitis and subse-

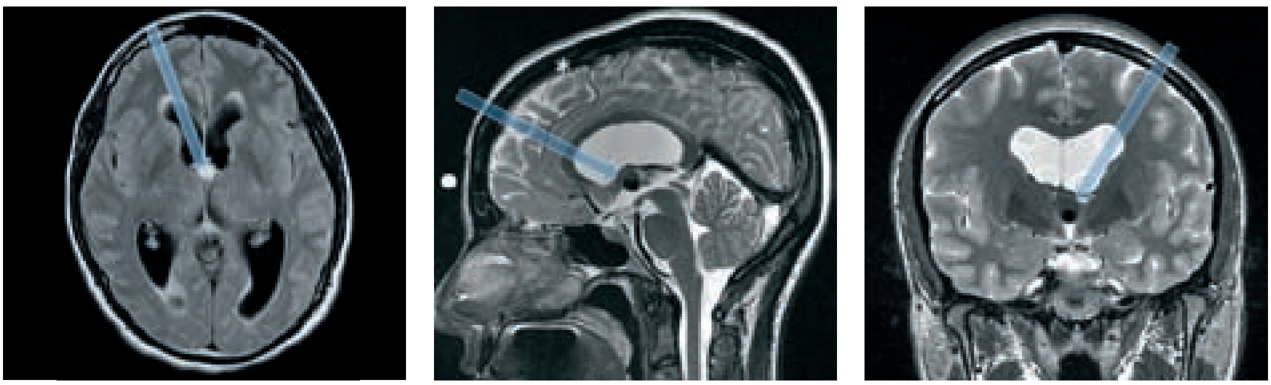


Fig. 67 *These MR images in an axial, sagittal and coronal plane have a superimposed trajectory intended for endoscopic removal of a colloid cyst of the third ventricle. The diameter of the endoscopic sheath has been taken into account to more accurately reflect structures at risk. The coronal suture is depicted with an asterisk.*

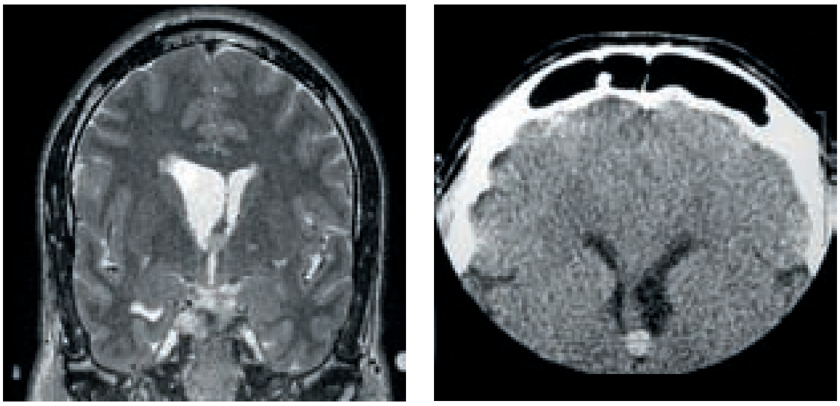


Fig. 68 *These two images illustrate the potential asymmetry regarding the frontal horns of the lateral ventricles in patients with a colloid cyst. An endoscopic approach is favored using the larger frontal horn.*

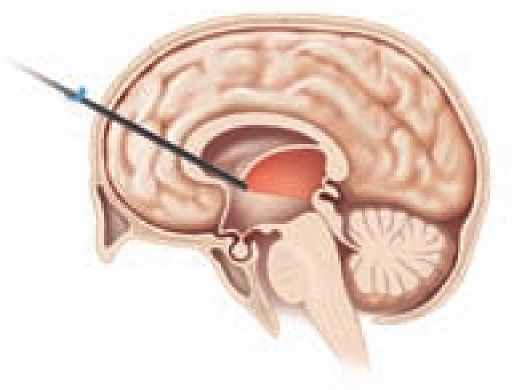


Fig. 69 *Using a 30 degree angled lens the endoscope is rotated once within the lateral ventricle in order to achieve a superiorly directed view into the third ventricle.*

quent hydrocephalus that may occur as a result of intraventricular spillage of colloid material. With increasing familiarity with the surgical procedure it is not necessary to prepare the surgical site in anticipation of a possible craniotomy except when the cyst is large (> 2 cm in diameter). Because of variability in each patient's anatomy, surgical planning is critical in optimizing the surgical goal and reducing potential morbidity. Integrated stereotatic navigation is always used for surgical planning and optimizing ventricular cannulation (Fig. 67). Laterality should be determined based on a preoperative MRI with emphasis on the relative size of the frontal horns of the lateral ventricles and the dimensions of the foraminae of Monro (Fig. 68) . Because the intent is to work below the ipsilateral column of the fornix, an entry site is used that is far forward of the coronal suture. In a sagittal dimension, the ideal trajectory passes just above the floor of the anterior horn, through the foramen of Monro, and below the roof of the third ventricle. In an axial and coronal plane, a trajectory is selected that passes between the head of the caudate and the column of the fornix into the foramen of Monro. The entry site that is selected with stereotactic guidance is marked on the skin surface prior to the surgical preparation. Regardless of the position of the entry site, a curvilinear incision is planned on the hair line with a variable length. A longer incision is needed to allow more anterior retraction of the scalp. In patients with a receding hairline the incision is alternatively placed within a forehead crease.

Once the frontal horn of the lateral ventricle is entered, the anatomical landmarks of the frontal horn are identified. Using a 30-degree angled lens the endoscopic is then rotated to offer a superiorly directed view toward the roof of the third ventricle; the site of attachment of the colloid cyst (Fig. 69).

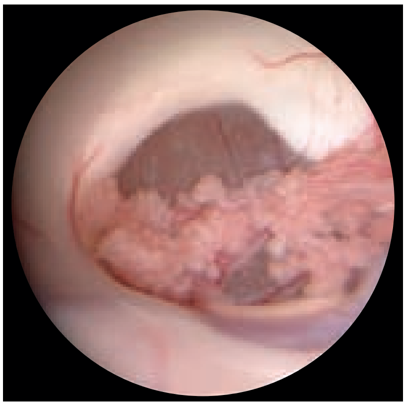


Fig. 70 *This figure illustrates an endoscopic view of a colloid cyst obstructing the foramen of Monro from a right frontal approach.*

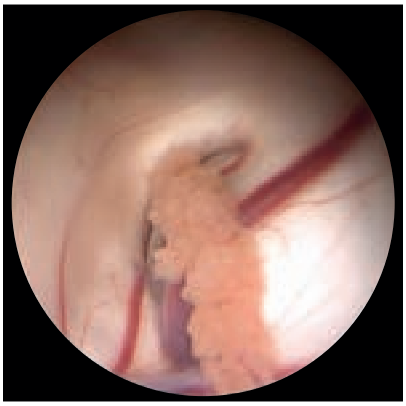
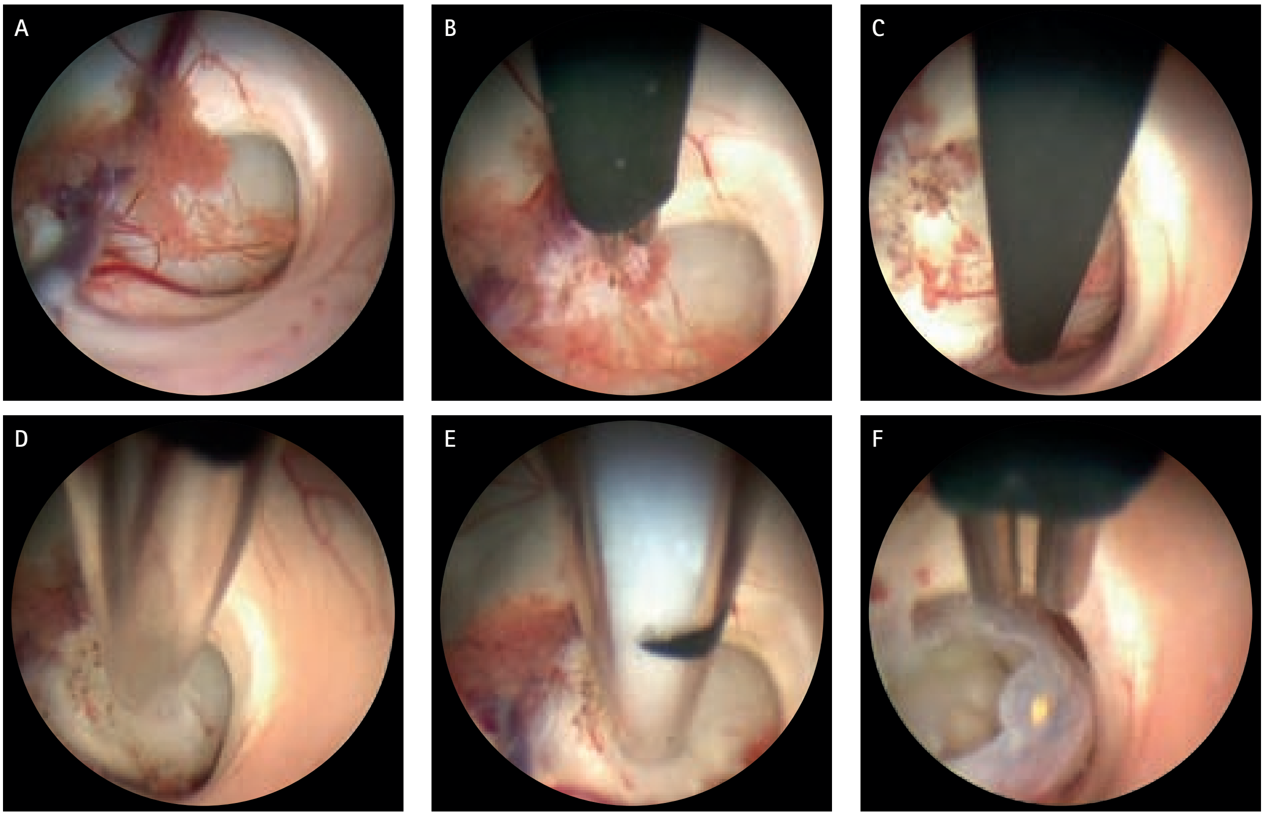


Fig. 71 *From a left frontal approach the colloid cyst within the third ventricle is not readily seen (left). The choroid plexus overlying the surface of the cyst is coagulated to improve the exposure (right).*

The endoscope is then navigated toward the foramen of Monro where typically the wall of the colloid cyst is in clear sight obstructing the foramen of Monro (Figs. 70, 71). Generous bipolar coagulation of the choroid plexus is used to gain better visualization of the lateral cyst surface. Bipolar forceps are utilized to bluntly dissect the cyst wall away from the walls of the third ventricle. This coagulation device (without current) is used to push the cyst wall away from ependymal surfaces. When sufficient space exists between the cyst and the walls of the third ventricle, power is then applied to coagulate the cyst surface. Perforation of the cyst wall by either sharp dissection or electrocautery is utilized followed by aspiration of the cyst contents. A graduated 6-French endotracheal suction catheter that has had the distal fenestrations removed is preferred (Fig. 72). This clear cannula allows direct visualization of the contents being suctioned. This ability is very helpful in gauging the strength of suction applied and in discontinuing aspiration if choroid plexus gets inadvertently aspirated. It is critical that aspiration only be applied once the tip of the device is placed within the cyst wall, thus avoiding rapid evacuation of CSF from the ventricular compartment. Utilizing suction aspiration the contents of the cyst can usually be fully evacuated. The viscosity of some contents may require repeated clearing of the cannula due to frequent clogging. With partial evacuation the cyst can commonly be drawn into the foramen with grasping forceps. This manuever positions the lesion applied aspiration and coagulation. The superior aspect of the cyst can be dissected away from the roof of the third ventricle by using a rotary motion with grasping forceps in effect pulling the cyst in an inferior direc-



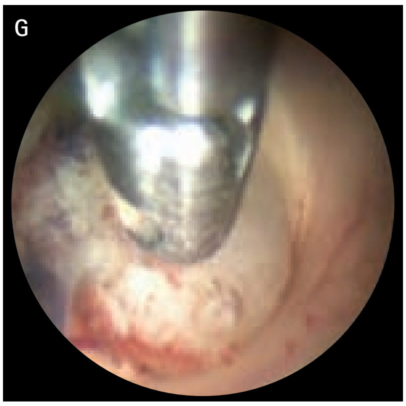


Fig. 72 *Endoscopic removal of a colloid cyst is demonstrated in this series of intra-operative images at the time of a right frontal approach. Initial exposure of the colloid cyst reveals complete obstruction of the foramen of Monro (A). The choroid plexus is generously coagulated to increase exposure and provide hemostasis (B). The cyst walls are then pushed away from the ependymal surface of the third ventricle prior to applying coagulation (C). The cyst contents are then aspirated with a clear cannula (D) which provides continuous visualization of the suctioned contents (E). Once partial evacuation of the cyst is accomplished (F) the cyst is sequentially mobilized into the foramen with grasping forceps (G) where further aspiration, coagulation, and removal can occur.*

tion toward the floor of the ventricle. When visualized, adherent portions of choroid plexus should be coagulated and sharply divided (Fig. 72).

Repeatedly using these maneuvers one of two situations usually occur. First, the cyst may freely separate from the confines of the third ventricular roof. If this situation occurs then the cyst should be removed by extracting the entire endoscope (Fig. 73). Because of the difference in size between the cyst and the working portal (1-2 mm) any attempt to extract the cyst through the sheath runs the risk of dislodging the cyst into the ventricular compartment. The second frequent scenario that occurs during endoscopic colloid cyst removal is that the cyst is entirely evacuated of contents leaving only adherent membrane. That membrane is then generously coagulated followed by sharp dissection. Some portions of the cyst wall may not be amenable to further removal due to adherence with venous structures. Any membraneous remnants should be generously coagulated and not subject to forced extraction. Once the removal is complete, inspection of the third ventricle for residual clot is performed. Residual hematomas within the third ventricle are removed using aspiration applied directly to the clot if present. The placement of an externalized ventricular drain is advocated on an individual basis depending upon the degree of intraventricular hemorrhage. Commonly, externalized drains are discontinued the day after surgery based on normal intracranial pressures and postoperative imaging failing to indicate any appreciable hematoma within the third ventricle (Fig. 74).

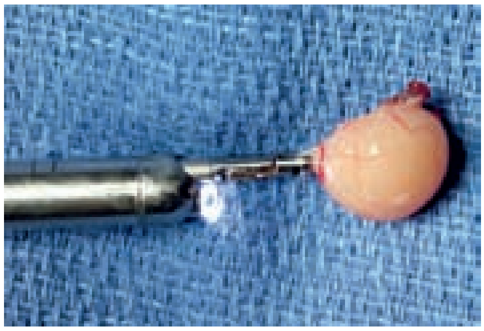


Fig. 73 *This colloid cyst was removed by withdrawing the entire endoscope, sheath, and working instrument while the tumor is securely held with grasping forceps. Some sharply dissected choroid plexus is seen on the top of this specimen.*

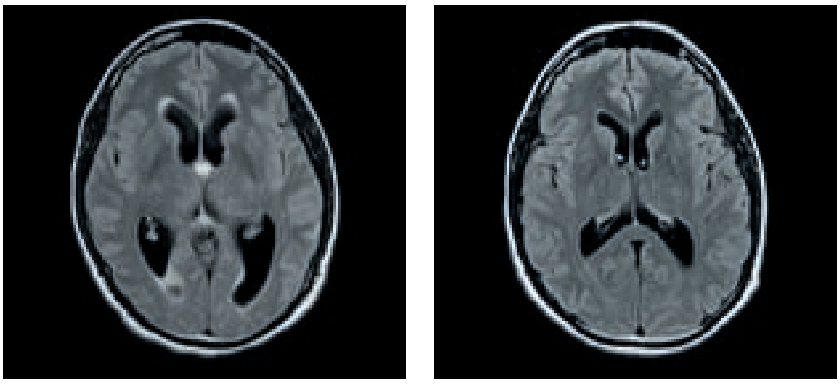


Fig. 74 *Axial FLAIR sequences are shown that indicate the total endoscopic removal of a colloid cyst. Comparison of the pre-operative(left) and postoperative (right) images demonstrates complete tumor removal, partial reduction of ventriculomegaly, and resolution of transependymal fluid resorption.*

Endoscopic Tumor Biopsy

Patient Selection

Endoscopic tumor biopsy is a relatively straightforward procedure that can have a profound impact on the management of patients with intrventricular brain tumors. This role is of particular importance in patients in which the subsequent oncologic management may not require aggressive tumor removal. Thus, a patient in whom the potential diagnosis includes tumors such as a germ cell tumor or hypothalamic/optic pathway glioma would be an ideal candidate for a minimally invasive endoscopic sampling. The majority of these pathologies occur in young patients and hence patient age is influential in the decision making process regarding the role of endoscopic tumor biopsy. A patient with a clinical suspicion of CNS germ cell tumor with positive serum tumor markers (βHCG, αAFP) represents a relative contra-indication for endoscopic tumor sampling. The tumor morphology also plays a role in assessing the potential for safe endoscopic biopsy. In short, only tumors that exhibit an exophytic component into the ventricle are logical candidates for endoscopic tumor biopsy. Subpendymal tumors that do not present into the ventricular system even though they may distort the ventricular walls can be difficult to locate intra-operatively and alternative methods of tumor sapling should be considered.

Surgical Technique

Surgical planning with navigational guidance will result in less torque on cortical and subcortical tissues and hence is an important adjunct for endoscopic tumor biopsy. Once the tumor is visualized cupped biopsy forceps are used to sample the tumor (Fig. 75). Sites of sampling are chosen that most likely represent pathologic tissue, are relatively void of surface vascularity, and require as little torque as possible. The small samples of tissue obtained with cupped forceps are challenging for accurate pathologic interpretation and every attempt should be made to minimize artifact from pre-sampling cautery. Therefore, the use of coagulation on the tumor surface, as logical as that may seem, should be avoided prior to sampling. Varying degrees of venous hemorrhage invariably occur with cupped biopsy forceps, the majority of which will be adequately controlled with continuation irrigation, balloon tamponade or electrocautery (see above). The number of samples should be governed by pathologic interpretation and no more tissue than is absolutely necessary is taken in an effort to reduce intraventricular hemorrhage.

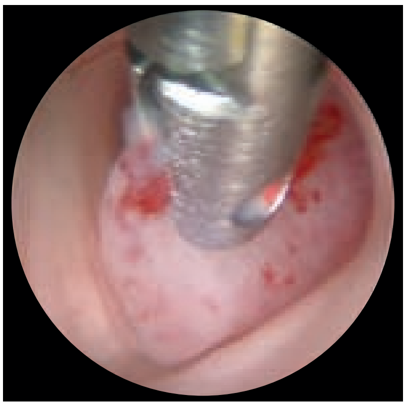


Fig. 75 *The endoscopic view shows biopsy forceps being used to sample a posterior third ventricular tumor.*

The patient with a posterior third ventricular tumor or pineal region tumor and noncommunicating hydrocephalus represents an excellent candidate for simultaneous endoscopic tumor biopsy and ETV (Figs. 76, 77). While the patient represents one of the best surgical candidates for endoscopic

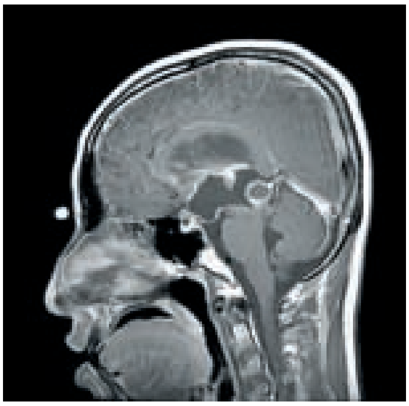


Fig. 76 *This preoperative sagittal MRI is from a 13 year-old female who presented with diabetes insipidus and headache. Serum tumor markers were negative and a simultaneous ETV and tumor biopsy were performed. The child was successfully treated without further surgery for a CNS germinoma.*

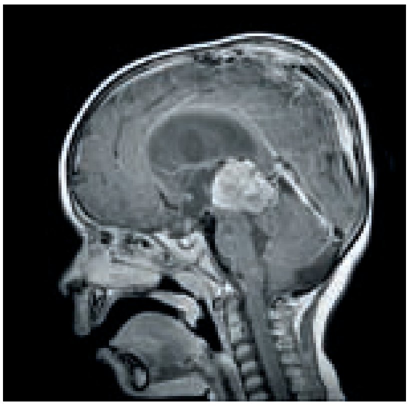


Fig. 77 *This MRI was performed on a 13 month-old male who presented with signs and symptoms of hydrocephalus. A simultaneous ETV and tumor biopsy was performed. The child underwent total microsurgical removal of a pineal region juvenile pilocytic astrocytoma on an elective basis and remains shunt independent.*

surgery, the situation can represent a challenging procedure. Navigating the endoscope into the limited space of the posterior third ventricle and sampling tumors that are variably hemorrhagic contribute toward this challenge. Since the optimal trajectory for ETV (coronal entry) and pineal region tumor biopsy (frontal-precoronal entry) are distinct a single or dual entry site will need to be chosen if a rod lens endoscope is used (Figs. 78–80). It is advised to choose a technique that best suites the individual patient based upon the ventricular size, the relative position of the tumor, the dimension of the massa intermedia, and the surgical goal. Typically, a combined approach through a single burr hole mandates that the entry site be located midway between the optimal entry sites for either separate procedure. This single approach is best used when the tumor is anterior to the massa intermedia, when the massa is small, when the degree of ventriculomegaly is severe, or when the tumor size obviates any consideration for total tumor removal. Alternatively, when tumors are recessed behind the massa intermedia, when the degree of ventriculomagely is modest, when tumors may be amenable to total removal (< 2cm), or when the massa intermedia is large, two sites of entry are advocated; one being optimal for the tumor and the other being optimal for the endoscopic third ventriculostomy. These features are outlined in Table 2.

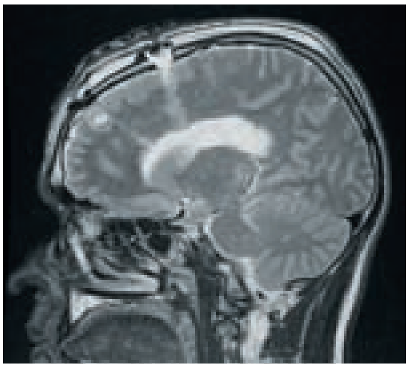


Fig. 78 *This postoperative sagittal MR image illustrates the two different tracts used to perform a simultaneous ETV and pineal region biopsy. The distance between these two trajectories, each selected with intra-operative navigational guidance, would pose a potential risk from excessive manipulation of the endoscopic sheath if a single entry were used.*

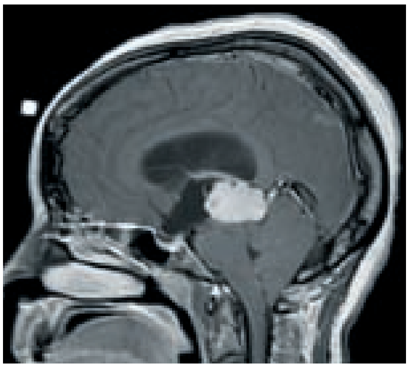


Fig. 79 *This sagittal pre-operative MRI on a patient who would be considered a good candidate for simultaneous ETV and tumor biopsy using a single trajectory. The ventricles are large, the massa intermedia is small, the tumor is anterior to the massa intermedia, and the tumor is too large for consideration for total endoscopic tumor removal.*

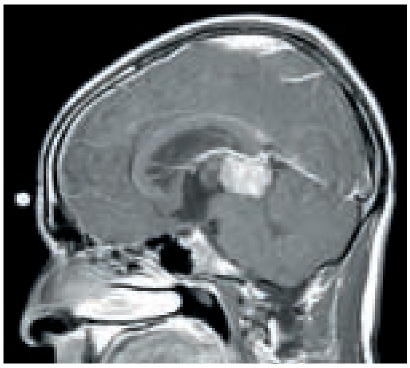


Fig. 80 *The patient shown in this sagittal MRI has a pineal region tumor that is situated posterior to the massa intermedia. The large size of the massa also decreases the potential space between that structure and the floor of the third ventricle. These features led toward simultaneous ETV and tumor biopsy using dual trajectories.*

Entry	Ventricular Size	Massa Intermedia	Tumor/Massa Relationship	Surgical Goal
Single	Large	Small	Anterior/inferior	Biopsy
Dual	Small	Large	Posterior/superior	Removal or Biopsy

Table 2 *Features used in selecting between a single or dual trajectory for simultaneous ETV and pineal region tumor biopsy.*

Although fiberoptic or steerable endoscopes optimally suited for this combined procedure the smaller working channels, the greater potential for disorientation, and the decreased image resolution associated with these endoscopes all have limited their wide-spread appeal.

When performing simultaneous ETV and tumor biopsy it is preferred to perform the ETV prior to tumor biopsy. This order is advocated since the most pressing clinical condition (i.e. noncommunicating hydrocephalus) should be definitively addressed prior to any visual obscuration by hemorrhage that invariably occurs with tumor biopsy.

Endoscopic Tumor Resection

Patient Selection

Primary endoscopic resection of solid tumors within the ventricular compartment is a challenging aspect of intraventricular endoscopy. Attempts at purely endoscopic tumor removal should only be performed once a significant degree of familiarity and experience are obtained through other neuro-endoscopic procedures. The major limitation to purely endoscopic solid tumor removal is the lack of compatible instrumentation designed for tissue ablation. However, patients with small, non-mineralized, and avascular tumors are excellent candidates for primary endoscopic removal. These are typically small tumors located at the foramen of Monro or posterior third ventricle (Figs. 81–83). Tumors greater than 2 cm in diameter become increasingly difficult to remove given the limitation of instrumentation. Larger tumors that are pedunculated at the ependymal surface are also good candidates for endoscopic removal (Fig. 84). In this situation, the pedunculated

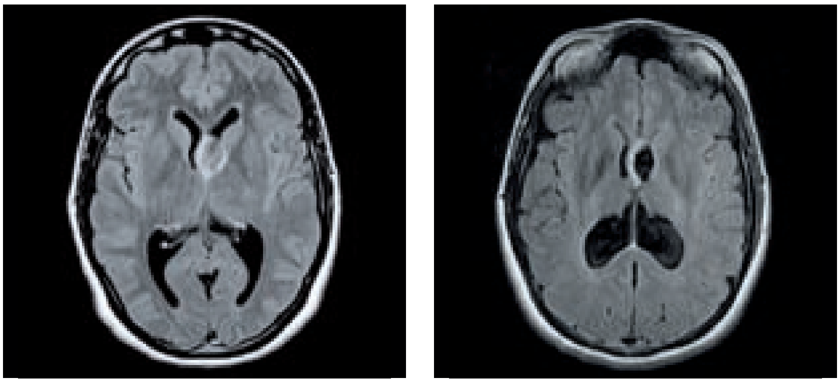


Fig. 81 *Pre-operative (left) and postoperative (right) axial FLAIR MR images are shown from patient that underwent purely endoscopic removal of a low grade tumor from the left foramen of Monro.*

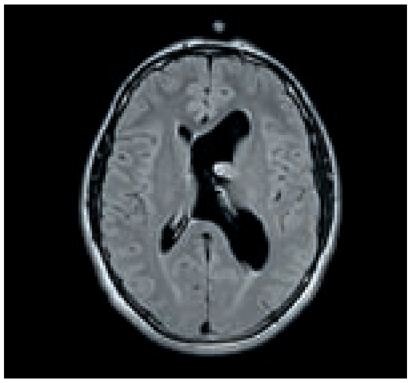


Fig. 82 *This axial MRI demonstrates an intraventricular tumor that is a very good candidate for endoscopic removal; the tumor is relatively small, the ventricle is dilated, and the tumor-ependymal interface is not large.*

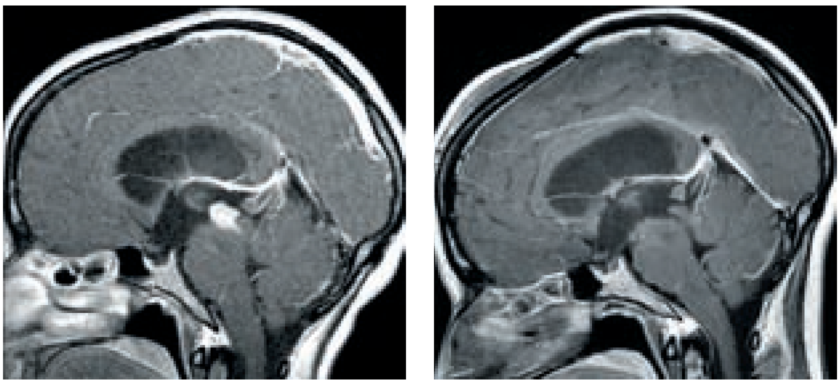


Fig. 83 *This third ventricular ependymoma shown in the preoperative MRI (left) was removed (right) using a purely endoscopic approach through a far frontal entry site.*

aspect of the tumor is first controlled with coagulation and sharp dissection followed by removal of the tumor in a piecemeal fashion or by delivering the tumor in total through the pathway of the sheath.

Variables that can limit complete endoscopic tumor removal are nearly impossible to predict based on current imaging techniques. Firm tumors or vascular lesions are major limiting factors. When a patient is being considered for purely endoscopic tumor removal noncontrast CT can be used to estimate the degree of mineralization based on the presence or absence of calcification.

Fig. 84 *The choroid plexus papilloma seen in this sagittal MRI of the brain is a very good candidate for a purely endoscopic removal given the small pedunculated attachment.*

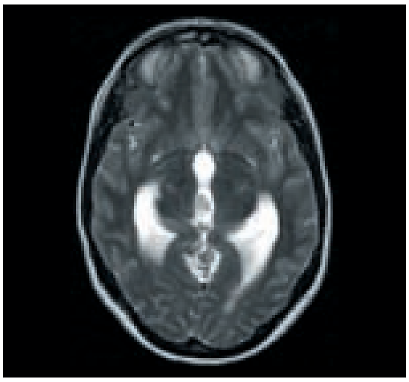


Fig. 85 *This axial T2 MRI demonstrates a third ventricular tumor that was targeted from a left frontal approach. This entry was selected to maximize the visualization of the thalamic-tumor interface on the right. The T2 sequence is very useful for assessing the degree of parenchymal invasion.*

Surgical Technique

Integrated stereotatic navigational guidance is important to obtain a direct approach toward the tumor surface. An angled solid lens system is preferred given the variability in viewing angles within a restricted field. The optimal surgical plan is obtained through careful inspection of high-resolution MRI scans in three dimensions. The T2 weighted sequences are very helpful in delineating tumor margins and potential sites of tumor attachment. For third ventricular and pineal region tumors, the laterality of the entry is governed by any eccentricity of the tumor (Fig. 85). Simply stated, a contralateral entry site optimizes tumor visualization and minimizes the need to torque on the ipsilateral diencephalon. For tumors situated posterior to the massa intermedia, the endoscopic path lies below that structure.

At the time of tumor exposure, cupped biopsy forceps should be utilized initially prior to the application of any energy source to ensure the best opportunity for pathologic interpretation. Once the specimen has been obtained for histologic diagnosis, the tumor is then removed sequentially, utilizing electrocautery or laser, cupped biopsy forceps, and suction aspiration (Fig. 86). The application of electrocautery or laser within the tumor parenchyma alters the consistency of the tumor, so as to allow aggressive suction aspiration. Again, suction should only be applied once the aspirator is placed within the parenchyma of the tissue, so as to avoid CSF evacuation. Continuous irrigation is utilized to maintain a clear visual field. Hemostatsis is maintained as discussed above. Once the entire solid tumor has been removed electrocautery is utilized at the site of ependymal attachment to decrease any potential for microscopic residual tumor. As was described for endoscopic colloid cyst removal, the use of a ventricular drain is decided on an individual basis (see above).

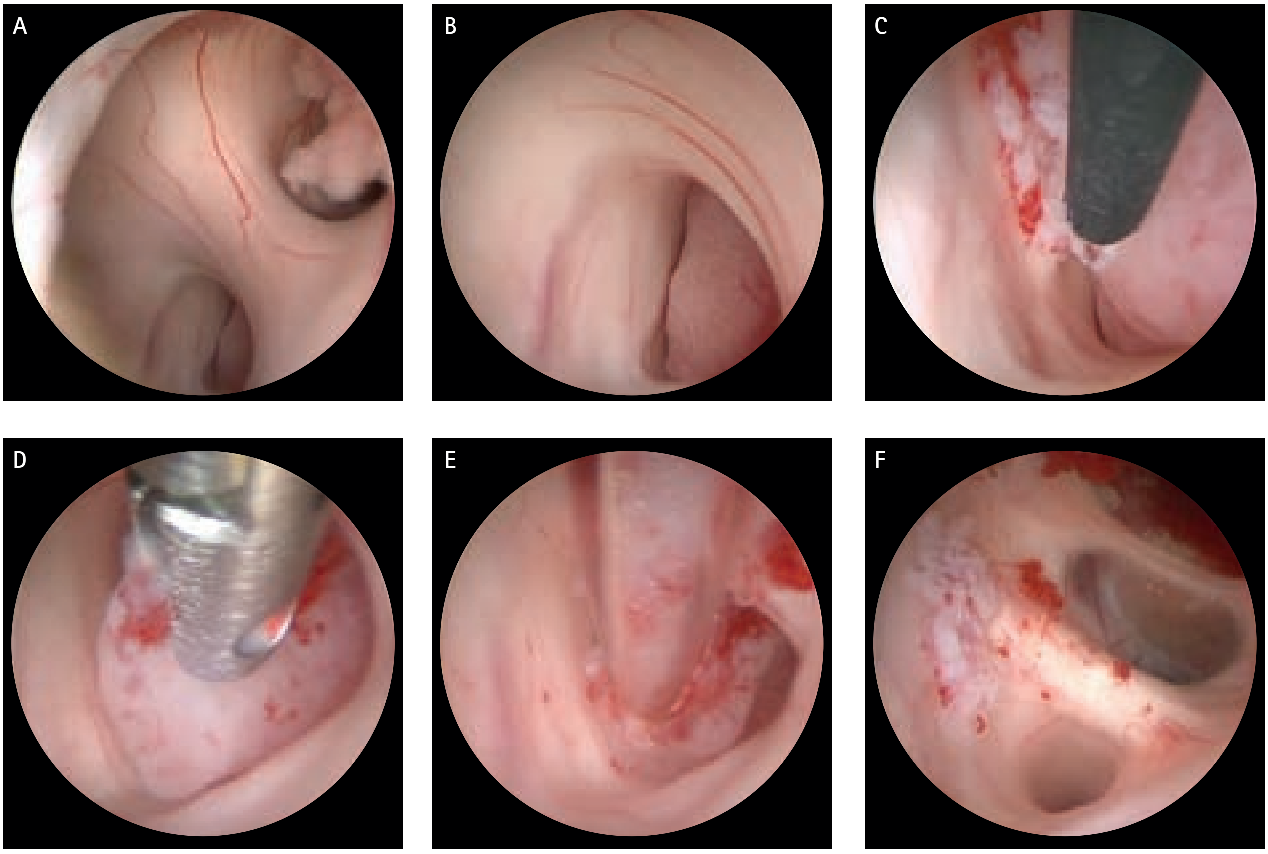


Fig. 86 *This series of endoscopic photos illustrates a left frontal approach and removal of a third ventricular tumor (shown in Fig. 86).; (A) view from the left foramen of Monro shows the massa intermedia and choroid plexus within the third ventricle, (B) the tumor in the third ventricle is seen just below the massa intermedia, (C) the bipolar cautery is being used to separate the tumor from the right (contralateral) hypothalamus, (D) biopsy forceps are used to sample and mobilize the tumor, (E) the clear suction aspirator is used to remove tumor tissue using a variable surgeon-controlled device, (F) the posterior third ventricle following removal of the tumor mass offers a clear view of the aqueduct, the habenular and posterior commissures, and the pineal recess.*

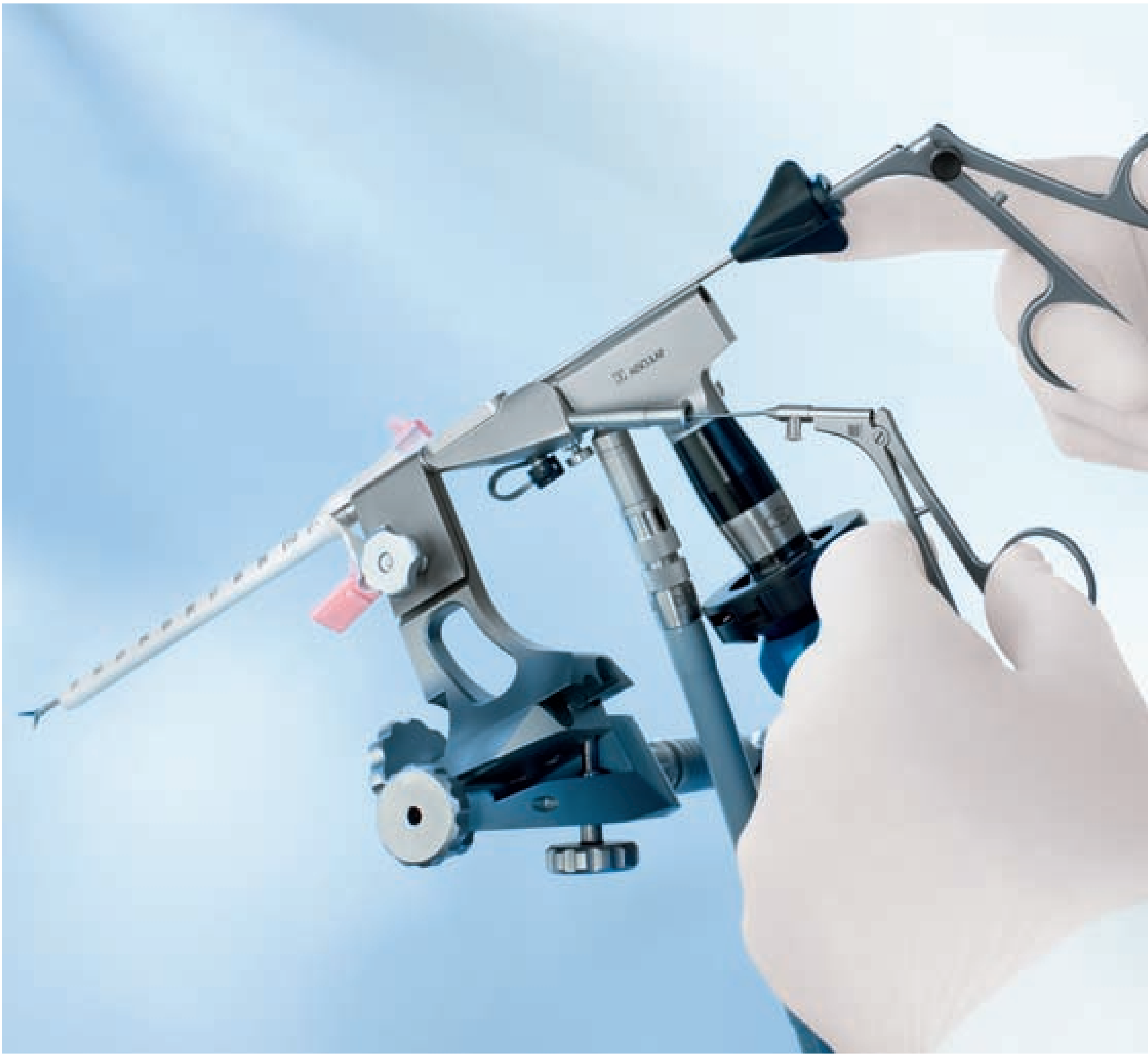
Abbreviations

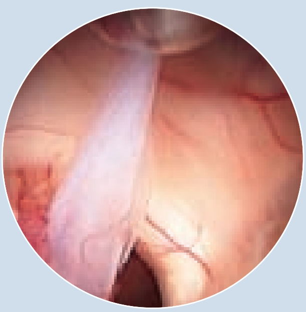
AFP	alphafetoprotein
AS	aqueductal stenosis
BA	basilar artery
CCD	charged coupling device
CINE	cinematographic
CSF	cerebral spinal fluid
CSP	cavum septi pellucidi
CT	computed tomography
CV	cavum Vergae
ETV	endoscopic third ventriculostomy
EVD	externalized ventricular drainage
FLAIR	fluid attenuated inversion recovery
GCT	germ cell tumor
HCG	human chrionic gonadotropin
LM	Liliequist's membrane
MRI	magnetic resonance imaging
NPH	normal pressure hydrocephalus
PPI	prepontine interva
Fr	french

Acknowledgements

Mr. Thomas Graves of Thom Graves Media provided all artist's illustrations. Cadaver images were generously supplied by Dr. Robert Reisch.

MINOP® Intraventricular Neuroendoscopy Equipment





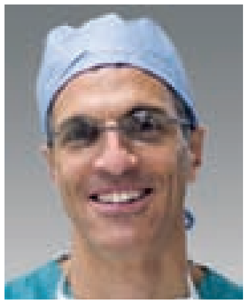
"The genesis of endoscopic surgery within the ventricular compartment can be attributed to the development of small caliber rod lens optics, fiberoptic light transmission and dedicated instrumentation. Since the advent of intraventricular endoscopic surgery, neurosurgeons have applied the technology to treat a number of disorders. While the enthusiasm has been great and the full potential not yet realized, a major benefit to the patient has been proven for selected conditions. Most notably the treatment of non-communicating hydrocephalus, management of patients with pineal region tumors, fenestration of intracranial cysts, and removal of colloid cysts have all been shown to provide significant benefit and reduced morbidity compared with conventional treatment strategies.

The benefit in minimally invasive endoscopic procedures is analogous to that of any endoscopic procedure, namely minimal tissue disruption, enhanced visualization, improved cosmetic results, shorter hospital stay, and less surgical morbidity. The surgeon willing to utilize intraventricular endoscopic surgery is first responsible for attaining a considerable degree of familiarity with the technology, relevant anatomy, and the surgical procedures. Given the relative nascence of the field, the discipline is only now being commonly implemented in training programs. Hence, for those that have not had the opportunity to have endoscopic surgery as part of their formal training, it is strongly recommended that the surgeon participates in established practical courses in endoscopic neurosurgery, such as the courses from the Aesculap Academy.

Once fluent with the endoscopic equipment, more advanced procedures can be performed with greater familiarity and experience. It is anticipated with future generations of neurosurgeons that the endoscope will be an indispensable part of the neurosurgeon's armamentarium given the unmatched image resolution and minimally invasive qualities.

This foreseeable integration will expectantly be paralleled with continued evolution in compatible equipment to suit the needs of an expanding repertoire.

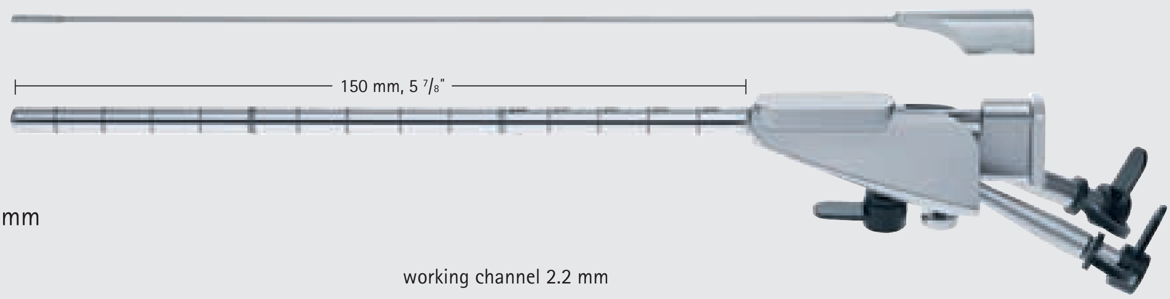
Few neurosurgical procedures demand a degree of familiarity with equipment as do neuroendos-copic techniques. This feature is somewhat explained by the recent introduction of the neuroendoscope as well as the delicate nature of the equipment. The basic components of any neuroendoscopic procedure include the endoscope and trocar, a camera with light source and monitor, as well as compatible instrumentation."



Mark Souweidane

MINOP® Trocars

- Ultra-smooth tip of trocar for atraumatic insertion into the brain
- Single obturator for working channel enables insertion of the trocar, under visual control, with the scope
- Large MM-length inscription on the outer shaft of the trocar
- Conical entry of working channel for intuitive insertion of instruments into trocar
- Attachment on top of trocar for improved handling and universal connection of peripheral devices



FF399R

MINOP® Trocar,
Outer diameter 6 mm

4 channels:

scope channel, diam. 2.8 mm

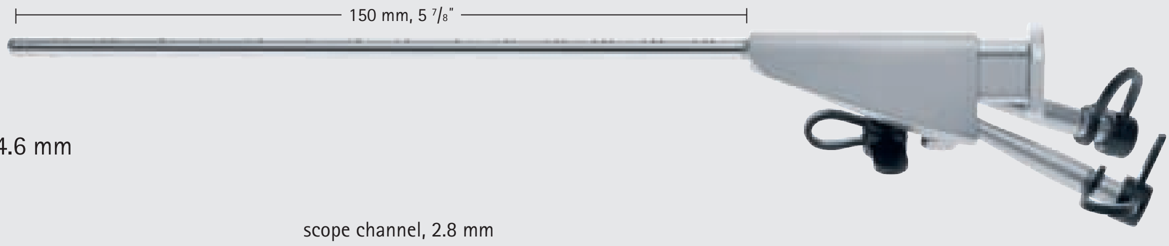
working channel, diam. 2.2 mm

irrigation channel, diam. 1.4 mm

overflow channel, diam. 1.4 mm

including 4 obturators
for all channels

FF398R



MINOP® Trocar,
Outer diameter 4.6 mm

3 channels:

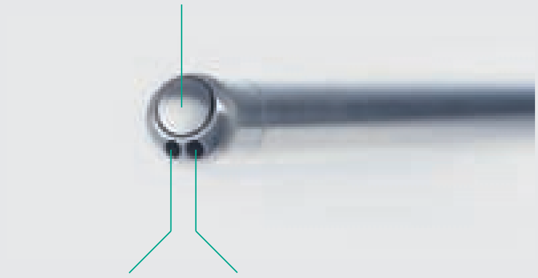
scope channel diam. 2.8 mm

irrigation channel diam. 0.8 mm

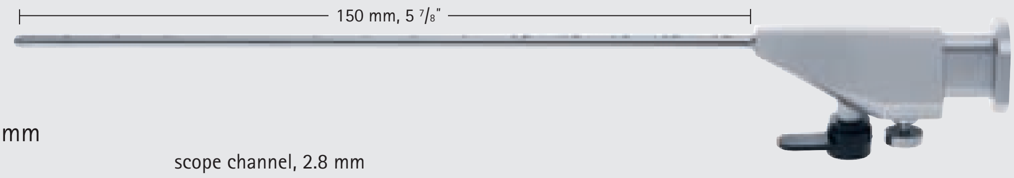
overflow channel diam. 0.8 mm

including one obturator for scope channel

one sealing cap for pressure balance in scope channel



FF397R



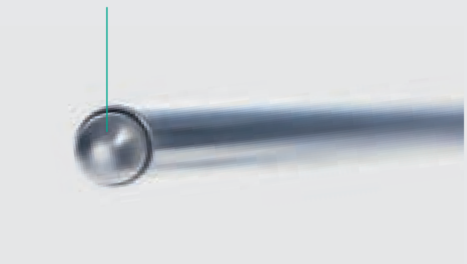
MINOP® Trocar,
Outer diameter 3.2 mm

1 channel:
single chanel for scope

inclding one obturator

optic channel, diam. 2.8 mm

one sealing cap for pressure balance in scope channel



MINOP® Endoscopes

- FULL HD compatible scopes
- Rust-proof steel outer casing for problem-free reprocessing
- The external tube is made from a high strength special alloy for superior breaking resistance
- Optimised fibre optics provide more light
- Service-optimised construction reduces maintenance costs
- Highly rectified optical systems
- Autoclavable/Steris/Sterrad

PE184A

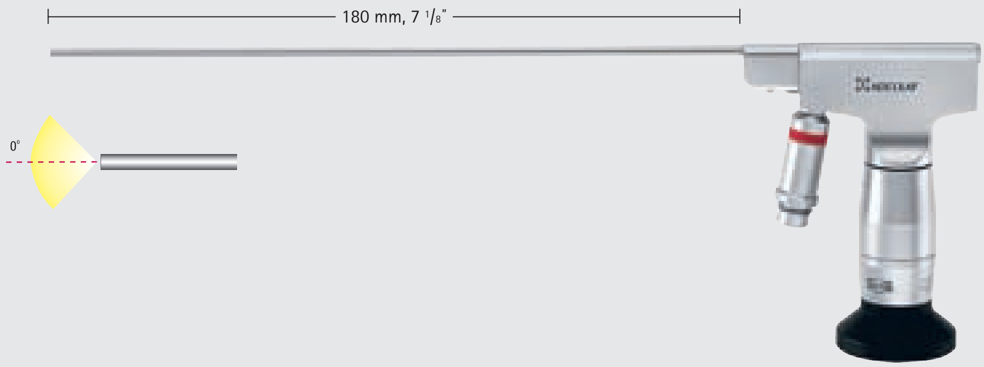
MINOP® Endoscope

Direction of view 0°
(green ring)

Shaft diameter 2.7 mm

Shaft length 180 mm

Autoclavable



PE204A

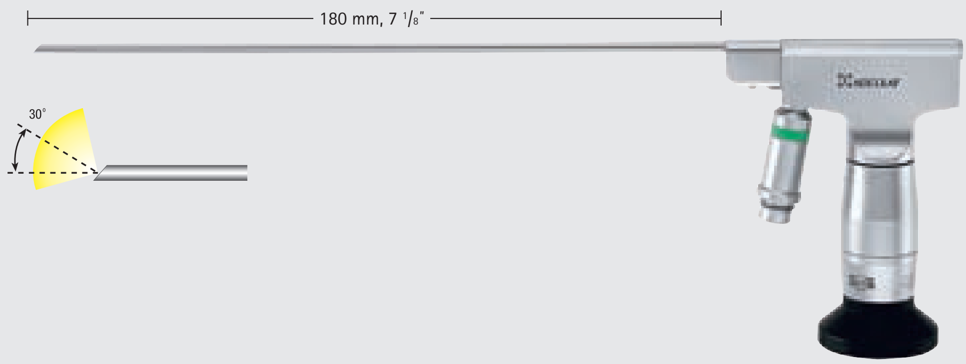
MINOP® Endoscope

Direction of view 30°,
upwards (red ring)

Shaft diameter 2.7 mm

Shaft length 180 mm

Autoclavable



MINOP® Rigid Instruments

Instruments

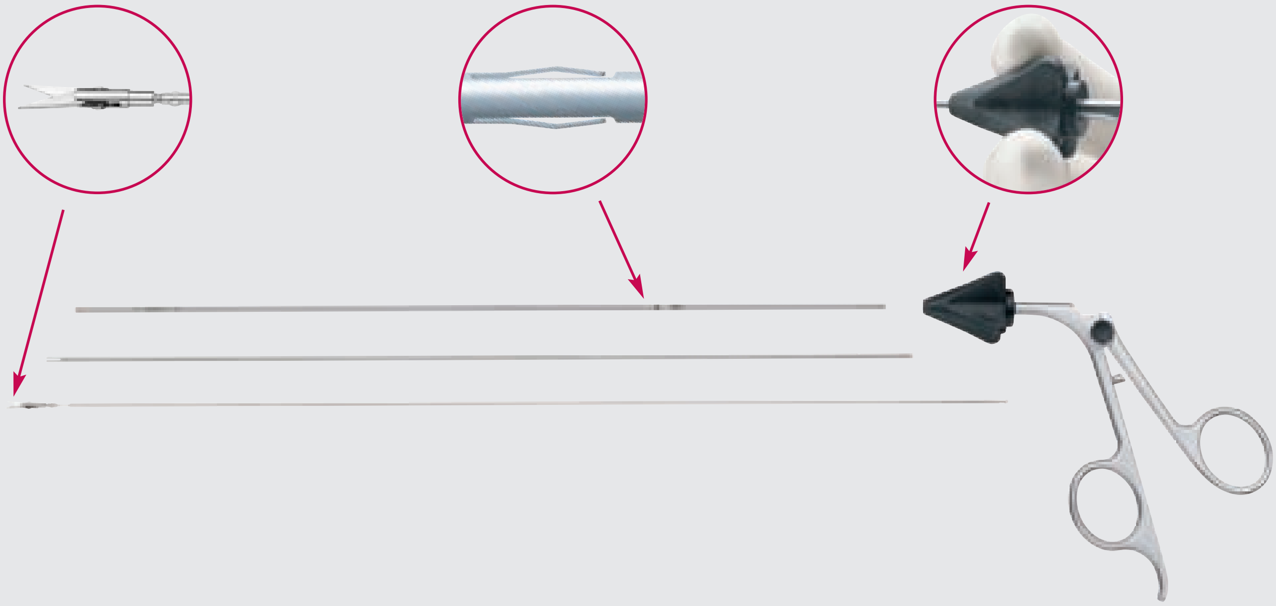
- Shaft length 265 mm
- Diam. 2.0 mm
- Fully detachable for reprocessing
- High precision instrument tip

Tactile Feedback

- Integrated tactile feedback delivers small resistance indicating that instrument tip emerges from the trocar
- Improves safety and control during insertion of instruments

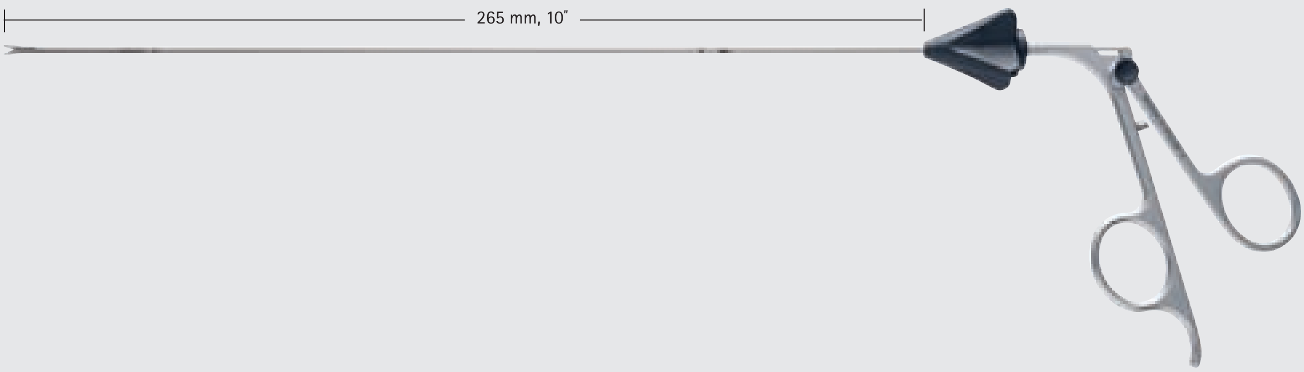
Rotating Knob

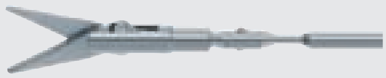
- By rotating the knob slightly with index finger, the tip of instrument turns equally
- No need to turn/rotate instrument with the entire arm/handle
- Improves safety and precision of neuroendoscopic surgery
- Integrated safety mechanism in instrument shaft



MINOP® Rigid Instruments

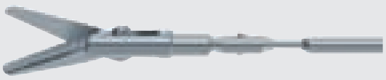
Ø 2mm **Instrument complete:** Handle · outer tube · jaw part with inner tube





FF385R

MINOP® micro scissors
sharp / sharp

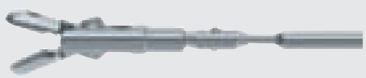


FF386R

MINOP® micro scissors
blunt / blunt

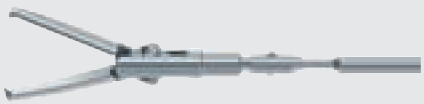
FF388R

MINOP® grasping and dissecting forceps



FF387R

MINOP® biopsy forceps



FF389R

MINOP® surgical micro forceps

MINOP® Rigid Instruments – Spare Parts

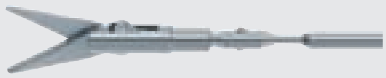
Ø 2mm Jaw part with inner tube for FF385R – FF389R

FF433R

Outer tube only for FF385R – FF389R

FF432R

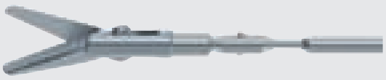
Instrument handle only for FF385R – FF389R



2/1

FF435R

MINOP® micro scissors
sharp / sharp



2/1

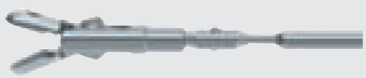
FF436R

MINOP® micro scissors
blunt / blunt

2/1

FF438R

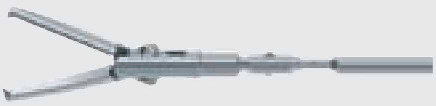
MINOP® grasping and dissecting forceps



2/1

FF437R

MINOP® biopsy forceps



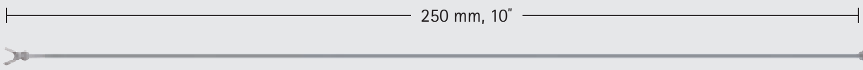
2/1

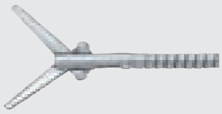
FF439R

MINOP® surgical micro forceps

Tactile Feedback
If you want to upgrade your MINOP system with tactilke feedback, simply order a new outer tube FF433R for all your instruments

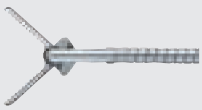
MINOP® – Flexible Instruments





FF373R

Micro scissors



FF374R

Micro grasping and dissecting forceps

FF378R

Micro biopsy forceps

Ø 1mm 1.0 mm instruments for bi-instrumental work

Flexible instruments:

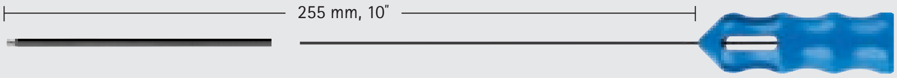
- For bi-instrumental / bi-manual neuroendoscopic surgery
- E.g. grasping and cutting, grasping and coagulating, grasping and fenestrating
- To be used through irrigation or overflow channel of the MINOP® trocar FF399R
- Diam. 1.0 mm, shaft length 250 mm
- Non-detachable
- With irrigation port for reprocessing/cleaning

MINOP® – Electrodes

GK361R

Blunt electrode, diam. 1.1 mm

1:1



GK363R

Needle electrode, diam. 1.1 mm

1:1

GK364R

Hook electrode, 45°, diam. 2.2 mm

1:1

GK365R

Hook electrode, 70°, diam. 2.2 mm

1:1

GK362R

Hook electrode, 90°, diam. 2.2 mm

1:1

GK366R

Hook electrode, 180°, diam. 2.2 mm

1:1

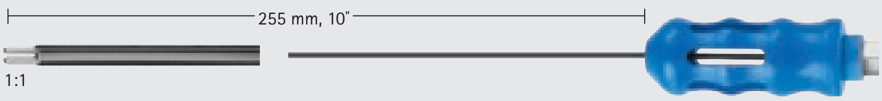
GK245

Monopolar cable suitable
for GN300, GN640

BIPOLAR ELECTRODES

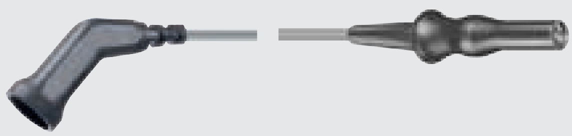
GK360R

Fork electrode, diam. 2.1 mm



GN073

Bipolar cable suitable
for GN060, GN300



MINOP® – Suction Cannula

MINOP® Disposable Suction Cannula

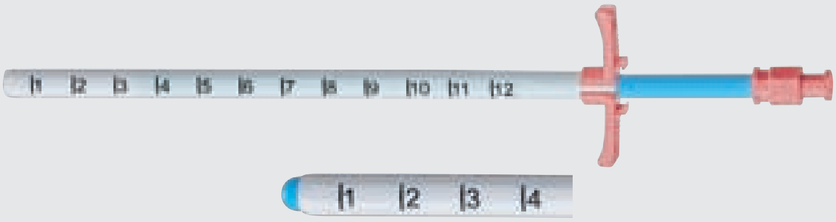
- For removal of cystic intraventricular lesions
- For puncturing the floor of the 3rd ventricle
- With depth marking, interval of 5 mm
- Outer diameter of 2.0 mm
- Suitable for working channel of MINOP® trocar FF399R
- Available with blunt or sharp tip suction cannula
- Optional control of suction
  - via thumb plate or
  - via syringe
- Single-use, sterile packaging

FH606SU	FH607SU
Suction cannula, blunt tip 0°, diam. 2.0 mm	**Suction cannula,** sharp tip 30°, diam. 2.0 mm

MINOP® – Disposable Introducer

MINOP® Disposable Instroducer

- 19 Fr disposable introducer set including obturator and sheath
- Especially for MINOP® trocar FF399R
- Introducer sheath protects the brain while inserting and removing the endoscope/trocar
- Round & blunt obturator tip for atraumatic insertion into the ventricles
- Depth scale for precise positioning and perfect control
- Easy to peel with side handles



FH604SU

Introducer,
19 Fr

MINOP® – Storage

FF358R

For MINOP® trocars and scopes

Storage rack with silicone protection cushioning

Bottom and lid

Only for reprocessing, not for transportation/shipment

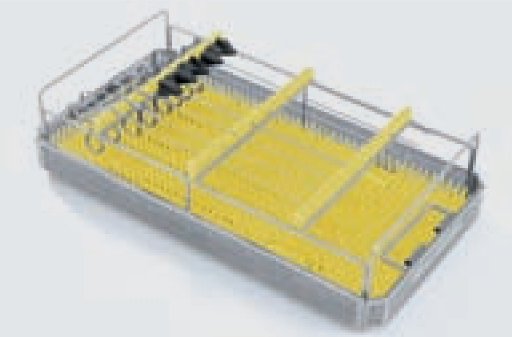
FF359R

For MINOP® instruments and electrodes

Storage rack with silicone protection cushioning

Bottom only, lid not necessary

Only for reprocessing, not for transportation/shipment



JN444

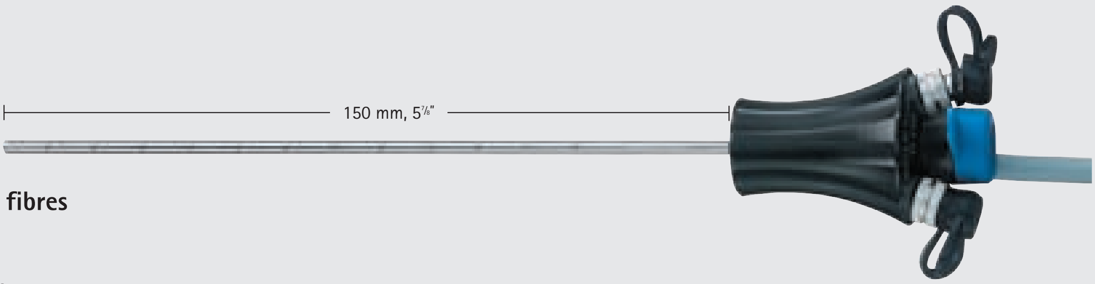
Container body 1/1
without base perforation
(L/W/H 592/274/187)

JK486

Container lid 1/1, blue

Paediscope

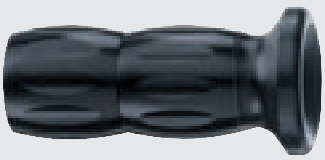
PF010A



Endoscope shaft with integrated optical fibres

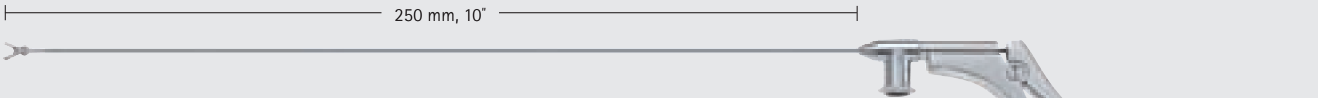
- 30.000 pixel fiber optic
- Fibres integrated in rigid shaft for high precision and control
- 3.0 mm outer diameter for minimally invasive pediatric surgery
- Light-weighted and ergonomic design
- Black handle can be hold like a pencil
- Weight of camera ocular is far away from the operating site

PF011A



Ocular with focus

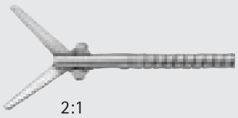
* for complete Paediscope, please order both PF010A and PF011A



Flexible instruments:
Diam. 1.0 mm, shaft length 250 mm, non-detachable

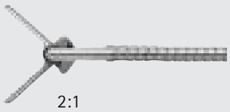
FF373R

Micro scissors



FF374R

Micro grasping and dissecting forceps



FF378R

Micro biopsy forceps

FH603SU

Paediscope Disposable Introducer

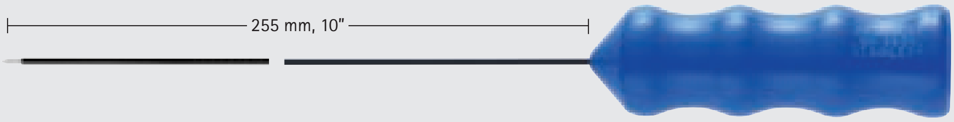
- 10 Fr disposable introducer set including obturator and sheath
- Especially made for Paediscope PF010A
- Introducer sheath protects the brain while inserting and removing the endoscope/trocar
- Round & blunt obturator tip for atraumatic insertion into the ventricles
- Depth scale for precise positioning and perfect control
- Easy to peel with side handles

Paediscope

GK363R

Needle electrode

1:1



GK361R

Blunt electrode

1:1

GK245

Monopolar cable
suitable for GN300, GN640

1:1

FF379R

For Paediscope shaft, instruments and electrodes

Storage rack with silicone protection cushioning

Bottom and lid

Only for reprocessing, not for transportation/shipment

JN440

Container basis 1/1
without base perforation
(L/W/H 592/274/90)

JK489

Container basis 1/1 lid
blue

M-TRAC – Mechanical Holding Arm

FF168R

M-TRAC

- Flexible holding device with mechanical fixation
- Assembly: flexible holding arm with integrated fixation bar
- Total length: 107 cm
- Length of fixation bar: 46 cm
- Diameter of fixation bar: 20 mm
- Total weight: 0.7 kg
- Holding force: 4 kg
- Easy mechanical fixation by clamping handle
- Small, flexible joints for fine positioning
- Autoclavable 134°C, 5 minutes
- Full range of accessories/ adapters for connecting Aesculap endoscopes, trocars and instruments
- Holding Arm fits into regular Standard 1/1 Container

FF280R

Flexible fixing element with ball joint suitable for RT040R and FF168R

RT090R

Flexible fixing element with sprocket suitable for RT040R and FF168R

FF151R

Rigid fixation element suitable for RT040R and FF168R

UNITRAC® – Pneumatic Holding Arm

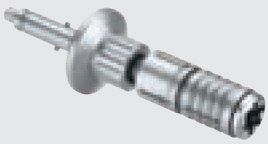
RT040R

UNITRAC®

- Single handed use
- Fast and sterile set-up in the OR
- Universal retraction and holding system with special accessories for neuroendoscopy
- Simple to assemble onto the OR table railing
- Integrated safety systems prevent collapse of holding arm if OR compressed air supply is interrupted
- Pneumatically-assisted system for direct connection to OR compressed air supply
- Flexible holding device with pneumatic fixation Diam. 20 mm
- To be used with JG901

JG901

Sterile drape for coverage of the Unitrac® arms, single-use product, package of 50 pcs.



RT020R

Quick connect adapter for use with sterile drape JG901allows the change of instruments after draping with JG901

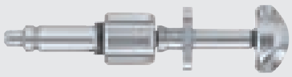
Adapters for UNITRAC® and M-TRAC

RT079R

Adapter
for fixation of angled neuroscopes PE486A, PE506A, PE526A

RT099R

Adapter
for fixation of MINOP® TREND handle, FH615

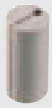


RT081R

Adapter
for PEEK-inserts RT082P – RT089P for fixation of trocars

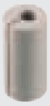
RT085P

PEEK-insert
with inner diameter 3.2 mm (for fixation of MINOP® trocar FF397R)



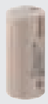
RT082P

PEEK-insert
with inner diameter 6.2 mm (for fixation of long or short ventriculo-scope trocar FF370R or FF372R)



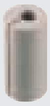
RT089P

PEEK-insert
with inner diameter 3 mm (for fixation of PaediScope® PF010A)



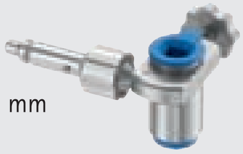
RT083P

PEEK-insert
with inner diameter 6 mm (for fixation of MINOP® trocar FF399R)



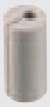
RT046P

Universal Holder
for Endoscopes diam. 3.0-7.5 mm



RT084P

PEEK-insert
with inner diameter 4.6 mm (for fixation of MINOP® trocar FF398R and FH601R)



RT055P

Universal Insert (Spare Part)
for Endoscopes diam. 3.0-7.5 mm

	MINOP® FF397R	MINOP® FF398R	MINOP® FF399R	Paediscope PA010A	Angled scopes PE486A	Angled scopes PE506A	Angled scopes PE526A	MINOP® TREND FH615	MINOP® TR FH601R
RT079R					●	●	●		
RT081R	●	●	●	●					●
RT082P									
RT083P			●						
RT084P		●							●
RT085P	●								
RT089P				●					
RT099R								●	
RT064R	●	●	●	●	●	●	●		●

Neuropilot® – Fine-positioning for UNITRAC® and M-TRAC

NeuroPilot® for IntraVentricular

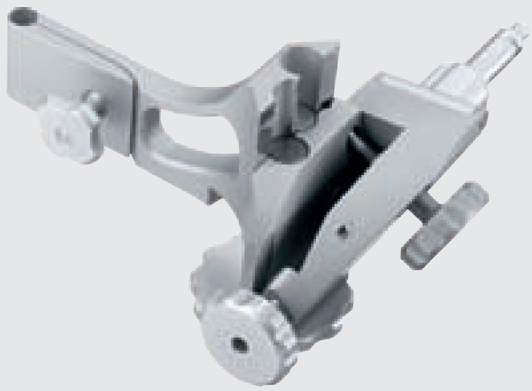
and Endoscope-Assisted indications with all Aesculap neuroendoscopes. NeuroPilot® is a new, unique steering device for neuroendoscopes. After positioning the neuroendoscope in situ, finest corrections or adjustments are necessary, to receive the optimal endoscopic image. With traditional holding devices, only a rough positioning is possible; precise and fine steering of the neuro-endoscope can be compromised.

NeuroPilot® offers a number of unique advantages:

- Optimal fixation of the neuro-endoscope in the NeuroPilot® and the holding device UNITRAC®
- Precise steering of the neuro-endoscope by three screws in the three-dimensional space
- Safe manoeuvring of the neuro-endoscope by defined movements in the sub-millimeter area
- Optimal positioning of the neuro-endoscope in situ

RT060R

NeuroPilot®
for intraventricular and endoscope-assisted indications with all Aesculap neuroendoscopes



RT061R

Insert for angled neuroscopes PE486A - PE526A with diam. 4 mm

RT062R

Insert for short ventriculoscope FF372R with diam. 6.2 mm

RT063R

Insert for MINOP® trocar FF397R with diam. 3.2 mm

RT064R

Insert for MINOP® trocars FF398R and FH601R with diam. 4.6 mm

RT065R

Insert for MINOP® trocar FF399R with diam. 6 mm

RT066R

Insert for PaediScope® PF010A with diam. 3 mm

Neuropilot® – Fine-positioning for UNITRAC® and M-TRAC

	MINOP® FF397R	MINOP® FF398R	MINOP® FF399R	Paediscope PA010A	Angled scopes PE486A	Angled scopes PE506A	Angled scopes PE526A	MINOP® TREND FH615	MINOP® TR FH601R
RT060R	●	●	●	●	●	●	●		●
RT061R					●	●	●		
RT062P									
RT063P	●								
RT064P		●							●
RT065P			●						
RT066P				●					

Neuroendoscopy Tower with FULL HD Camera and Touch Screen

PV875

Extension arm for flat panel display
VESA 100 Fixation

PV941

15" Flat panel display "Touch Screen"
for EDDY PV920

PV920

EDDY
Digital Documentation System

PV880

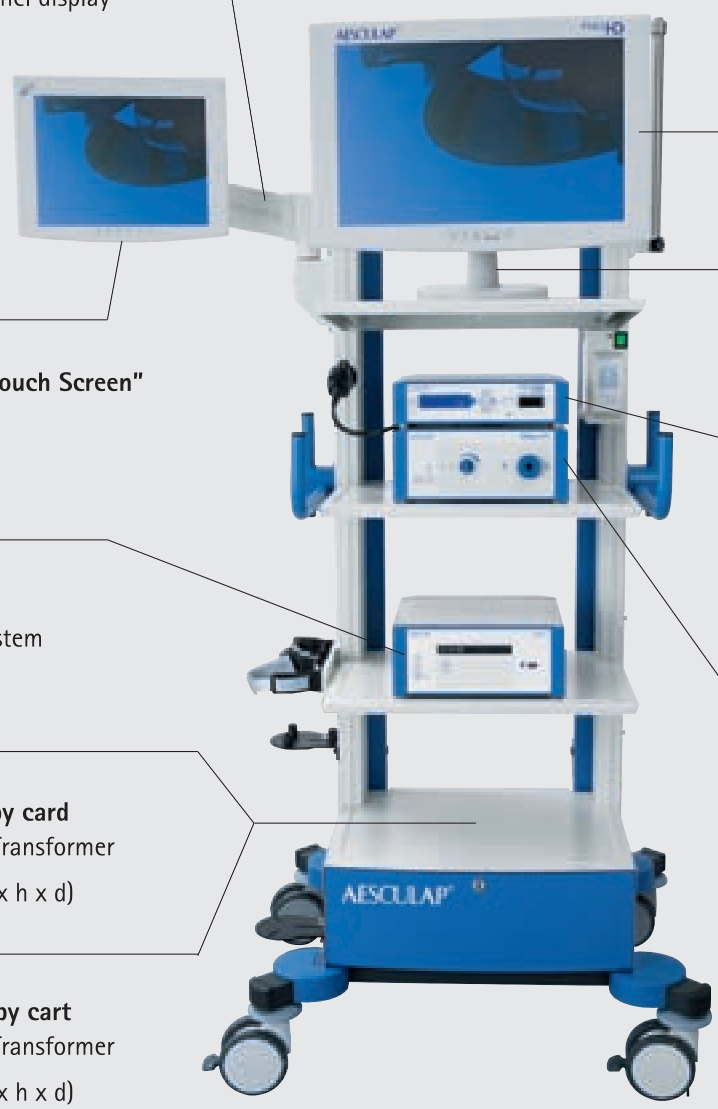
"Metro Junior" Endoscopy card
with integrated Isolating Transformer

835 x 1580 x 750 mm (w x h x d)

PV881

"Metro Classic" Endoscopy cart
with integrated Isolation Transformer

835 x 1580 x 750 mm (w x h x d)



PV946

24" Full HD flat panel

PV909

Monitor stand
for PV946

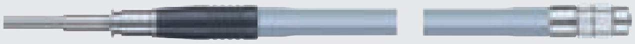
PV440

Full HD Camera system
consisting of CCU, 3 chip camera head, zoomcoupler PV126S, to be ordered separately

OP930

Xenon light source

OP914

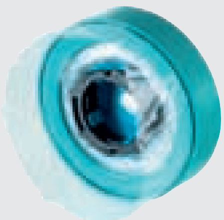


Full HD Light cable,
autoclavable, diam. 4.8 mm,
length 250 mm

JG904

Sterile Camera drape,
disposable, ring design,
package of 25

JG908SU



Closed sterile Camera drape,
15 cm diam. the optic can
be changed under sterile
conditions during surgery,
package of 10

Aesculap Academy
Neuroendoscopy Courses

Horizons of Knowledge. Competence to Master the Future.

AESCULAP ACADEMY

www.aesculap-neuro.com or
www.aesculap-academy.com

Innovative developments in the field of medical technology, sophisticated new treatment methods, increasingly more stringent requirements for hospital and quality management and, last but not least, a healthy interest in acquiring new knowledge have given rise to an enormous and ever-increasing demand for further and advanced training.

The Aesculap Academy enjoys a world-wide reputation as a leading forum for medical training and answers the demands of physicians and medical staff in OR, anaesthesia, ward, outpatient care and hospital management. The course program comprises a wide range of hands-on workshops, management seminars and international symposia.

Aesculap Academy courses are of premium quality and are accredited by the respective medical societies and international medical organizations. A scientific advisory board guarantees the selection of speakers and topics.

All of our courses are conducted by pioneering neurosurgeons who will address the theoretical knowledge of neuroendoscopy, cranial endoscopic anatomy, and clinical applications of neuroendoscopy. Each course includes extensive hands-on sessions or possibly live surgeries. Course attendees will benefit from discussions and analysis of real cases together with expert colleagues from all over the world. The training facilities of the Aesculap Academy in Berlin and Tuttlingen are traditional and spectacular locations for "sharing expertise".

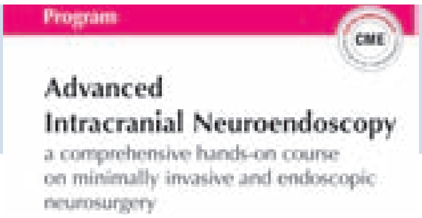
Competence to master the future – keep yourself fit for the future and ask for the latest course programme offerings, e.g.

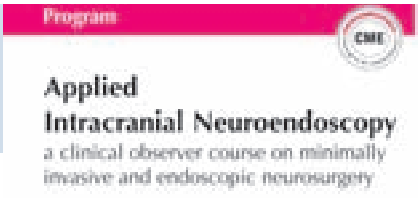
- "Basic" Neuroendoscopy Course
- "Advanced" Neuroendoscopy Course
- "Applied" Neuroendoscopy Course

Visit our website and register for one of the next neuroendoscopy courses -

www.aesculap-neuro.com or www.aesculap-academy.com
or contact your local B. Braun Aesculap representative.

"Pre-requisites of intracranial neuroendoscopy are valuable and user-friendly endoscopic equipment. However, despite of availability of dedicated systems, the endoscopic technique is not in routine use everywhere and neurosurgeons are often hesitant to use it. The cause of the aversion is often the steep learning curve. The goal of our Neuroendoscopy Courses is to facilitate the initial steps, thus giving a comprehensive overview in contemporary endoscopic techniques, including intraventricular, transcranial and transnasal applications. Didactic lectures by international experts give the necessary theoretical basis. Extensive hands-on laboratory allow basic anatomical studies and offer practical experience with endoscopes. Illustrative live surgeries show clinical application, giving advantageous tips in the every-day application of neuroendoscopy."





"Basic" Neuroendoscopy Course

The objective of the course "Basic Intracranial Neuroendoscopy" is to offer a comprehensive overview on endoscopic techniques in intracranial neurosurgery. Didactic lectures, extensive hands-on laboratory and illustrative live-surgeries are especially designed for newcomers in the field of neuroendoscopy, giving excellent theoretical and practical basis. Manuals and digital documentation of your own laboratory exercise provide an additional positive impact on your learning.

"Advanced" Neuroendoscopy Course

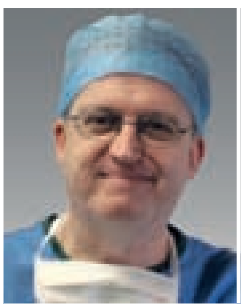
"Advanced Intracranial Neuroendoscopy" is designed for neurosurgeons with basic experience in neuroendoscopic techniques. The didactic lectures address the preoperative surgical planning as well as distinguished endoscopic techniques for cranial neurosurgery. Extended hands-on dissections and illustrative live surgeries demonstrate clinical applications in the daily routine offering important tips and tricks as well as valuable instructions for everyday use. The course is offered in two complementary parts. However, please note, that the both parts can be booked separately as well as in combination.

Part I (Endoscope-assisted Neurosurgery) concentrates on minimally invasive transcranial keyhole approaches and endoscope–assisted techniques dealing in a comprehensive way with the supraorbital, subtemporal and retrosigmoidal exposure.

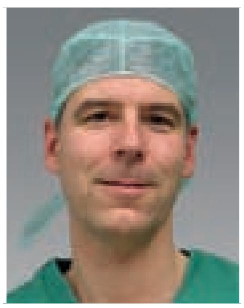
Part II (Endoscopic Transsphenoidal Surgery) deals with endoscopic techniques to treat sellar and parasellar lesions via the transsphenoidal route. Special attention will be given to extended skull base surgery.

"Applied" Neuroendoscopy Course

The course "Applied Intracranial Neuroendoscopy" offers a clinically oriented comprehensive overview on contemporary techniques in cranial endoscopic neurosurgery. Dedicated lectures, extensive case discussions and live surgeries will offer important tips and tricks providing valuable instructions for your everyday use. This event is a well recommended adjunct to the hands-on courses on "Basic Intracranial Neuroendoscopy" and "Advanced Intracranial Neuroendoscopy" in Berlin and Tuttlingen. In addition, you will have the opportunity to look behind the scenes of the headquarters and manufacturing plant of B. Braun Aesculap in Tuttlingen. Forming aneurysm clips yourself, experiencing how micro instruments are manually fabricated and visiting the famous Surgery Museum Asclepios are impressive parts of the course.



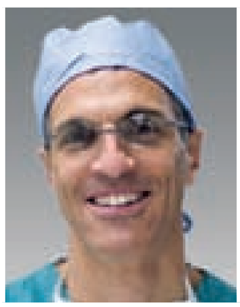
André Grotenhuis
Nijmegen, Netherlands



Nikolai Hopf
Stuttgart, Germany

Peter Nakaji
Phoenix, USA

Robert Reisch
Zurich, Switzerland



Mark Souweidane
New York, USA

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