Neuroendoscopy: Indications for Its Use

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Currently, one of the most exciting areas of growth in neurosurgery involves neuroendoscopy. As in the fields of general, gynecologic, orthopaedic, thoracic, and urologic surgery, neurosurgeons are exploring the utility of the endoscope and its changing technology. The use of endoscopes in neurosurgery is actually not new. In 1920 Mixter first reported using one to treat a hydrocephalic child. The early scopes suffered from poor illumination and the need for the surgeon to look directly through the scope, using it in a manner similar to a telescope. In the 1950s this changed with significant advances in endoscopic optics. Harold Hopkins, a professor of applied optical physics, improved the conventional solid glass rod lens system with a resulting improvement in the scope's image. He also developed "coherent" fiber bundle technology which made the flexible endoscope possible. These advances, coupled with better diagnostic testing (CT and MR scanning) and the miniaturization of video cameras, have resulted in the current explosion of interest in neuroendoscopy.

INSTRUMENTATION

Neuroendoscopic equipment is rapidly expanding, with regards both to the types of endoscopes available and to the instrumentation which can be used with them. This growth in equipment availability reflects the increasing indications for the use of the neuroendoscope.

There are two broad categories of neuroendoscopes available, namely, the rigid scope and the flexible scope. The rigid scope, as its name implies, is a scope which has a rigid shaft which cannot be deflected, and it therefore can house a series of lenses much like a telescope. This series of lenses delivers the image seen by the tip of the scope back to its eyepiece and the video camera. The image delivered can be magnified without loss of the image's resolution, and thus the image seen on the video screen with such a system is larger and of a sharper resolution. The other type of scope is flexible and delivers its image to the eyepiece using a bundle of fiber optic strands (a bundle typically containing 6000 to 10,000 or more optical fibers). The use of fiber optics instead of a series of lenses allows any portion of the shaft of the endoscope to bend without loss of conductance of the image from the tip of the scope to the eyepiece or camera. The image seen by the video camera is a summation of the images delivered by each of the fibers within the bundle. Because of this, the orientation of the fibers must be in the same relative position with regards to its neighboring fibers at both ends of the scope. The summated image is a collection of "pixels" with each pixel being the video information delivered by one of the optical fibers within the bundle. As there is a limit to the density of the packing of the fibers within the bundle, there is loss of a portion of the image due to the spacing between each fiber (i.e., there is nothing within this space which can conduct an image). Consequently, as the image conducted by the fiber bundle is enlarged, the spacing between each fiber becomes more obvious and the clarity of the image degrades. Thus the image size on the video monitor is a tradeoff between the size of the broadcasted image and its graininess. The graininess of the image can be decreased (and thus the clarity of the image increased) by increasing the density and number of fibers within the bundle. This is a major area of development currently for neuroendoscopy. What must be borne in mind, however, is that as the number of fibers increase for a given diameter of endoscope, its flexibility decreases; indeed, some of the "flexible" scopes which are currently being proposed should more correctly be referred to as semi-rigid scopes.

At present instrumentation available for use with the neuroendoscope is limited. Cupped and grasping forceps are available down to diameters of 1 mm, as are monopolar cautery units and ballooned catheters. Scissors have also been developed for 1-mm working channels. Bipolar, forked-tip cautery catheters have been developed for larger (2.3-mm) working channels. Suction catheters can be "jerry-rigged" for use in the larger working channels. These instruments have allowed for the development of third ventriculostomy, fenestration techniques, biopsy, and limited resection of mass lesions. Further development of neuroendoscopy awaits more effective cautery and resection instrumentation as well as a means of updating the surgeon as to the endoscope's tip location and the changing dimensions of the mass being resected.

THIRD VENTRICULOSTOMY

Prior to the availability of shunts, third ventriculostomy was the most favored treatment of hydrocephalus. In 1920 Dandy reported on splitting the optic chiasm and anterior wall of the third ventricle to communicate it with the prechiasmatic cistern.[1] He later altered the surgery, approaching the suprasellar cisterns via a subtemporal approach and opening the floor of the third ventricle just behind the infundibulum, communicating the ventricle with the interpeduncular cistern.[2] He reported a 39% success rate in the 92 patients on whom he performed this later procedure. On further analysis, he found that those over the age of one (n=29) had an 83% success rate while those under one (n=63 with 10 loss to follow-up) only had a 23% success rate. Scarff reported a 54% success rate with a 15% mortality rate in 44 patients upon whom he opened the lamina terminalis and, once inside the third ventricle, communicated the third with the interpeduncular cistern by making an opening between the infundibular recess and the mamillary bodies.[3] The mortality rates with these procedures were too high to sustain interest in them, however, once shunting materials became available.

As experience was gained with shunting of hydrocephalus and physicians grew to appreciate the incidence of morbidity and mortality of shunted patients with long-term follow-up, interest was rekindled in third ventriculostomy for the treatment of obstructive hydrocephalus. In 1968 Forjaz reported on 15 patients who had a shunt catheter percutaneously placed through the lateral and third ventricle penetrating its floor to rest straddling the floor with inlets in both the third ventricle and interpeduncular cistern.[4] In 1973 Guiot described 20 patients in whom he guided a leukotome to the floor of the third ventricle under visualization using a camera sitting in the lateral ventricle.[5] He then used the leukotome to make an opening in the floor between the mamillary bodies and the infundibular recess. He reported a 75% success rate in control of the hydrocephalus. Ten patients had the floor of their third ventricle opened using a stereotactically guided cannula with a 100% success rate by Poblete and Zamboni.[6] Vries used a rigid Hopkins-designed Storz scope to perform third ventriculostomies on five children with a 60% success rate.[9] Jones has had a similar experience with 54 patients.[10]

Currently, there is a consensus that obstructive hydrocephalus due to late onset of aqueductal stenosis is an indication for a third ventriculostomy.[10,11,12] This includes acquired aqueductal stenosis secondary to tumors in the tectum of the midbrain. The efficacy of a third ventriculostomy for other types of obstructive hydrocephalus is less clear. With regards to "congenital" hydrocephalus due to aqueductal stenosis, several authors have reported poor outcomes when treating the condition with third ventriculostomies postulating that there had been a congenital failure of the arachnoidal spaces to develop.[11,12] Jones, on the other hand, favors an attempt to treat the condition with a third ventriculostomy reporting a 60% success rate–a rate of success identical to that of his late-onset obstructive hydrocephalics treated with third ventriculostomies.[10] Interestingly, he described one infant who experienced a persistence in accelerated head growth for several weeks following creation of the third ventriculostomy prior to the expected deceleration in head growth and ultimately a return to the child's expected head circumference growth curve. He postulated that a brain swollen by hydrocephalus will close its arachnoidal spaces, and these spaces will slowly reopen after the third ventriculostomy is created. Only when the arachnoidal spaces are open will significant drainage of the ventricles start to occur. Kelly has reported some success treating hydrocephalus due to intrinsic brainstem gliomas with a third ventriculostomy.[11] He successfully treated seven patients with obstructive hydrocephalus due to intrinsic brainstem tumors. Finally, there is some support for the consideration of treating obstructive hydrocephalus due to Arnold-Chiari malformation with a third ventriculostomy. Jones has described success in 4 out of 10 patients with this condition whom he treated in this manner.[10] At NYU Medical Center, we have now treated 22 cases of late-onset aqueductal stenosis, and 11 cases of obstructive hydrocephalus due to a tectal plate tumor with a 90% success rate. We also have a 75% success rate in treating congenital aqueductal stenosis (4 cases). Only 40% of the third ventriculostomies done to treat hydrocephalus in children with end-stage brainstem gliomas have been successful (5 cases), and we have seen a 100% failure rate in the 5 infants with myelomeningoceles and associated hydrocephalus.

INTRAVENTRICULAR FENESTRATION FOR OBSTRUCTIVE HYDROCEPHALUS

Hydrocephalus due to multiloculated ventricles postventriculitis, suprasellar arachnoidal cysts, or trapped lateral ventricles can be difficult to manage, frequently requiring multiple shunts or open craniotomy. Not uncommonly, it is one of these entities which peeks a neurosurgeon's interest in neuroendoscopy. In 1986 Powers published a preliminary report on the use of endoscopes to treat two children with multiloculated ventricles due to ventriculitis.[13] He later reported on a larger series of seven patients undergoing endoscopic treatment of their multiloculated or trapped ventricles.[14] In three cases intraoperative complications occurred with no long term sequelae but resulted in the need for open craniotomy to treat their pathology. All seven patients were described as improved. Pierre-Kahn described his groups' experience in treating suprasellar arachnoidal cysts from 1972 to 1988 in a 1990 article. He described his groups' evolution in treatment, ultimately settling on the use of the endoscope to fenestrate the cysts into a lateral ventricle, frequently avoiding shunting all together. Heilman, in 1991, wrote on Cohen's experience treating eight patients with trapped or loculated ventricles between 1989 and 1990.[15] They were able to fenestrate either the cyst walls or septum pellucidum to create a single CSF space with the patients requiring only a single shunt.

We have had the opportunity to treat 5 children with multiloculated ventricles, 3 children with suprasellar cysts with obstructive hydrocephalus, and 5 children with trapped lateral ventricles. Unipolar cautery was used to fenestrate the suprasellar arachnoidal cysts into a lateral ventricle. In one case a prior existing shunt was left in place while in the other a new shunt (low-pressure PS Medical unishunt) was placed at the same setting. Several weeks after his operation, the second child re-presented with bilateral subdural hematomas requiring drainage. The shunt was upgraded to a Cordis Orbis-Sigma valve after a trail occlusion of the shunt showed that it was required. The five children with trapped lateral ventricles underwent fenestration of their septum pellucidum without complications. Three have subsequently required only a single shunt while two are shunt-free. The children with multiloculated ventricles have been somewhat more difficult to manage, and I have come to view these cases as the most difficult ones I do with the endoscope. The main problem is anatomical orientation given the distortion present. Ideally, one should start by entering the relatively normal portion of a lateral ventricle, identifying landmarks, and then proceeding to fenestrate the walls of any cysts bowing into the ventricles. This can be exceedingly difficult, however. Authors have described using the ultrasound through the anterior fontanelle as a means of orientation, but I have found this to be difficult at times.[15,16] What I find to be most helpful, in addition to starting in a normal area of the ventricle, is to maintain an awareness of how far the scope has been advanced into the head and in what direction. I correlate this with the MR image to get a general idea of the location of the tip. Most recently, I have been using the ISG Eleckta Viewing Wand to guide the working channel for the endoscope into position. The scope is then introduced through the working channel and the fenestration made. I find that this ability to know where I am working greatly improves the success of the procedure and radically shortens its duration. I have dealt with 5 of these children, successfully intercommunicating the loculations in 4 of them with 1 child experiencing severe nausea, vomiting, and dysequilibrium.

ENDOSCOPIC TUMOR BIOPSY AND RESECTION

Over the past several decades, articles have appeared discussing the merits of endoscopically assisted tumor biopsy and resection. In 1968 Apuzzo wrote on using the endoscope during stereotactic tumor biopsy.[17] In 1980 Jacques and Shelden published a series of articles discussing their techniques for endoscopically resecting intraparenchymal tumors.[18,19,20] Hellwig has reported on successfully performing biopsies on 50 brain tumors using a stereotactically guided endoscope with a 0% mortality or morbidity.[21] He believes that the endoscope enables him to better control postbiopsy bleeding and to ensure a complete evacuation of any associated cyst. Zamarano has performed biopsies on 53 tumors using a stereotactically guided endoscope in addition to 4 cases of radiation necrosis, 5 abscesses, and 1 cryptic AVM.[22] One of her tumor patients died postoperatively from a respiratory complication, and there were no other deaths.

Colloid cysts have also been targeted using the endoscope. In 1983 Powell reported on treating an isodense colloid cyst with associated hydrocephalus using an endoscope.[23] More recently Cohen has reported on a series of these cysts successfully treated using an endoscope.[24]

I have had occasion to use the endoscope on a child and an adult with a colloid cyst as well as four tumors: an intraparenchymal, cystic glioblastoma multiform; a low-grade glioma of the thalamus; a hamartoma of the thalmus obstructing the foramen of Monroe; and a giant cell subependymal astrocytoma. Using the endoscope, I aspirated the colloid cyst of the child easily and then cauterized its capsule with unipolar cautery to a point of complete involution. The child re-presented six weeks later symptomatic of a chemical meningitis. The MR scan showed the cyst to have regrown to 50% of the volume seen prior to the first surgery. An open resection was performed which was greatly complicated by arachnoidal adhesions. I found the cyst was actively leaking colloidal substance into the CSF. The second cyst was resected using cupped forceps to remove both the capsule and the cyst's extremely mucoid contents. I now believe that if the cyst wall cannot be resected with the endoscope, an open craniotomy should be performed immediately, especially in younger patients. With regards to the intraventricular tumors, I first used a single scope with a 1-mm working channel. The 1-mm channel limited the size of instrumentation, and I consequently found the resection to be laborious. I had a similar experience using a Nd:YAG laser fiber resecting tumor nodules within the GBM cyst. Additionally, both unipolar and laser cautery seemed inadequate in controlling larger vessels within the tumors. More recently, I have used a second working channel separate from the observing endoscope, much like that used for routine laparoscopy. This channel can be of any size (I have selected a 7-mm diameter shaft), and once in place it allows for the introduction of larger, rigid instrumentation for work on the tumor. While endoscopic resection of tumors holds great promise, better cautery and tissue removal techniques are needed as well as a less cumbersome guidance system than is now afforded by frame-based stereotaxis. These needs seem destined to be addressed in the near future.

OTHER USES FOR THE ENDOSCOPE

Over the years several other uses for the endoscope have been described. L'Espinasse performed the first ventriculoscopy in 1910 to fulgurate the choroid plexus in an attempt to treat hydrocephalus in an infant.[25] Dandy reported doing this on two patients in 1922, and more recently Griffith has described a series of patients treated in this manner.[26,27] The technique has not gained wide acceptance, however, due to a difficulty in identifying the subgroup of patients expected to benefit.

Several authors have published series of evacuations of intraparenchymal clots using the endoscope.[21,22] More interesting is the experience using the scope to aid in the evacuation of chronic, multiloculated subdural hematomas. Hellwig reported on eight patients treated through a burr hole with the scope being used to visualize and cut through the membranes to ensure communication between the loculations.[21] A single drain was then left for drainage. In no case did he have to reoperate.

Huewel has assembled an interesting series of 10 patients with syringomyelia (7 idiopathic and 3 posttraumatic) and 1 with a cystic intramedullary astrocytoma.[28] Through a 1- to $1^1/_2$–level laminectomy and 5- to 7-cm dural opening, a 2.5-cm myelotomy was made, and either a 0.85- or 2.3-mm flexible endoscope was advanced into the cavity. Visualized septa were lysed as the scope was advanced, and after removal of the scope, a silastic syringo-subarachnoidal stint was left. With a one-month to two-year follow-up, nine are improved and two stable. Subsequently, Hellwig has attempted this in a single patient with a satisfactory result being described.[21]

Finally, a multicenter trail of endoscopic placement of shunt cathetersis is currently under way. The question of the trial is, will the survival of the shunt be improved when the tip of the ventricular catheter is placed visually rather than using surface landmarks of the head?

CONCLUSION

We are in the midst of a clinical trial of endoscopy, and this is occurring in the setting of rapid application of computer-assisted graphics for intraoperative guidance in the neurosurgical operative theater. I am sure that in many areas the promise will be fulfilled. However, the surgeon using this technology must constantly remind himself or herself that this technology is investigational in all but a small number of indications and thus should be used accordingly. STI

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