Neuroendoscopy

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There is currently a great deal of interest in endoscopy in the field of neurosurgery. Given that the central nervous system is bathed in a clear fluid, the brain and spine have always seemed perfect environments in which to use endoscopes, and attempts have been made to do so since the early years of the century. The delicacy of the maneuvers required, the size of the endoscopes, and the rapid advances in other forms of neurosurgical technology all served to hamper the development of this field, until recently. Endoscopes with diameters of less than 1 mm are now available, as are endoscopes with irrigation and working channels in addition to a degree of controlled flexibility as small as 2.3 mm. The only limits to the greater use of endoscopes in the brain are human ingenuity and human expertise—arguably infinite resources.

The first recorded adventure inside the human ventricular system with a scope was before 1910. A Chicago urologist, Victor Darwin Lespinasse, used a urethroscope to look inside the heads of two children with hydrocephalus. Subsequently Dandy described his experience with removing the choroid plexus using an endoscope,[1] and Mixter performed the first endoscopic third ventriculostomy in 1923.[2] J. Laurence Pool was seemingly the first to use an endoscope in the spine in the 1930s[3] and while interest in spinal endoscopy waned for many years, it is now one of the areas of greatest growth. Neuroendoscopy has a long and interesting history.

INSTRUMENTATION

Neuroendoscopes were originally scopes for other applications placed in the brain. It is still possible to do much worthwhile endoscopy with scopes available in most hospitals, such as urological systems. There is no difference in the basic principles, but it is easier to use a system designed for use in the brain. Some specifically neurological considerations are worth noting, however.

Scopes may be rigid (as most urological systems are), flexible, or semi-rigid (i.e., pliable without being controllably flexible). As with any other tool, it is more important to have a clear idea of what one wants to achieve and how one intends to achieve it rather than be wedded to a specific instrument. It is a common misconception when starting endoscopy to expect to do complex things at difficult angles within the ventricular system. It soon becomes obvious that orientation is difficult to obtain and any maneuver performed through a bent scope is many times more difficult than when performed through a straight scope.

Rigid scopes have rod lens systems that give superb images, superb orientation, and illumination. While one can look in different directions with various angled scopes, they are still large and rigid. The smallest scopes are generally about 8 Fr., without

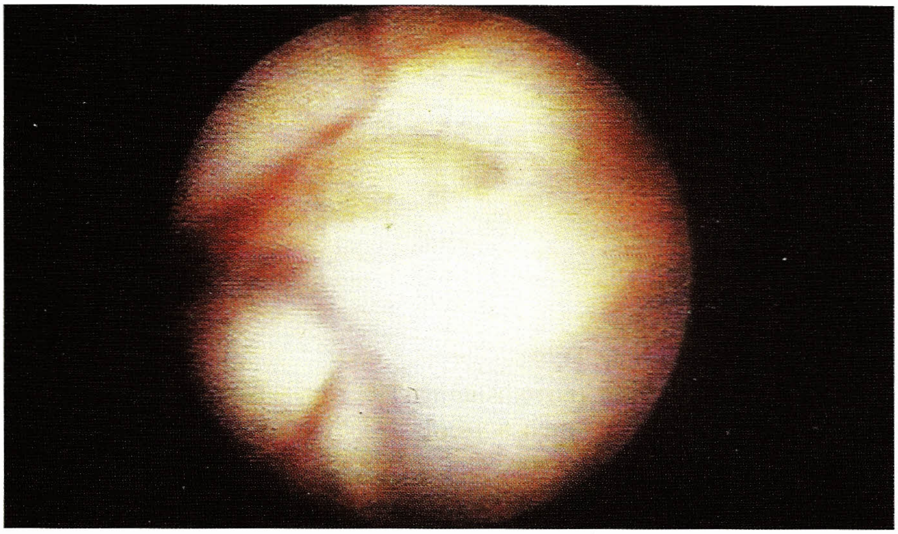

Figure 1. The foramen of Munro through a 1.2-mm fiberoptic scope. (Note the septal and thalamo-striate veins meeting at the foramen behind the anterior limit of the choroid plexus.)

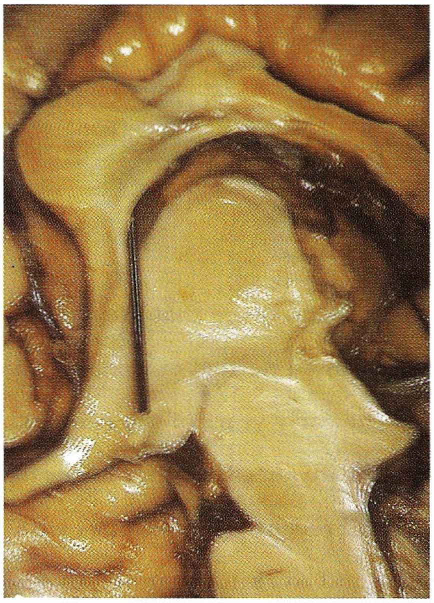

Figure 2. 1.2-mm scope in position for a third ventriculostomy. (Note that this brain has all the hallmarks of myelomeningocele. Small foramen, huge massa intermedia, thick floor of the third, making a third ventriculostomy difficult. Note also the beaking of the tectum.)

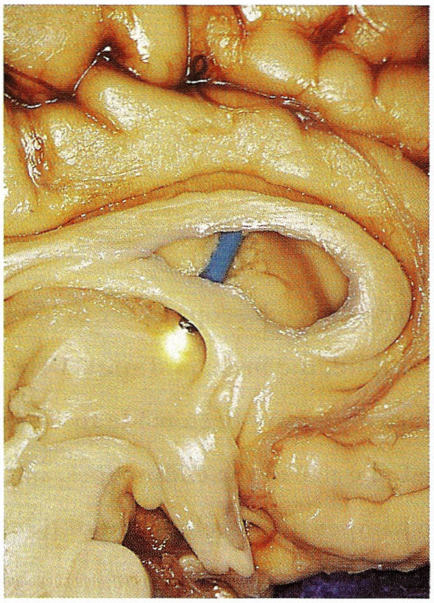

Figure 3. A 2.3-mm scope enters the foramen in a specimen without Chiari changes.

irrigation channels or working channels (Fig. 1). They range in diameter up to approximately 10 mm and may have multiple working channels for more extensive tumor work.

Flexible scopes are most useful for making one turn (e.g., for performing a third ventriculostomy [Fig. 2] and then looking backwards up into the pineal region when performing a biopsy of the tumor causing the hydrocephalus). More than one turn means that orientation is so frequently lost that it is not practical to work through such a scope. Flexible scopes, or scopes with some controllable flexibility, are available from just under 2 mm to just over 6 mm (Fig. 3). They use fiberoptics and consequently their optics are not as good as that of the rigid systems.

Semi-rigid scopes are less than 1.3 mm in diameter and are therefore generally small enough to fit inside a ventricular catheter (Figs. 4, 5). They may or may not include a small irrigation channel. They are useful because one can either put a slight bend in the scope itself without breaking the fibers and without losing too much in terms of orientation, or one can use their rigidity to dissect tissue with the scope itself. We use these scopes for a great deal of hydrocephalus work, reasoning that there is no more damage to the brain using a stylet scope than there would be placing a ventricular catheter, with the added benefit of being able to visualize the ventricle. Combinations of scopes may be used, obviously, to give two or more angles of attack through two or more burr holes. Using a peel-away catheter to access the ventricle allows one to use a number of instruments down the peel away in addition to a small scope to see the lie of the land. Once you have visualized your objective, what are you going to do with it? The op-

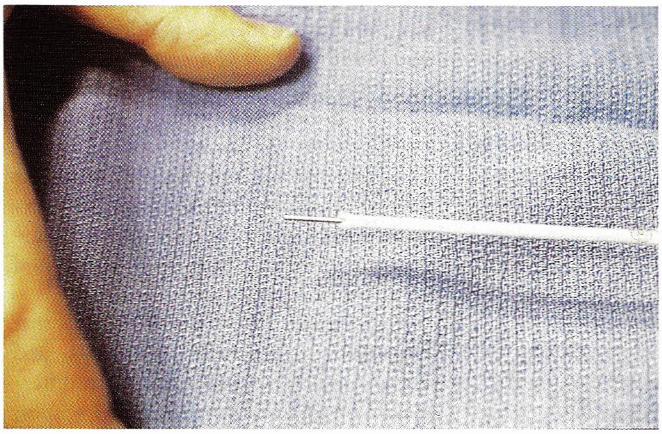

Figure 4. 1.2-mm scope protruding through a ventricular catheter tip.

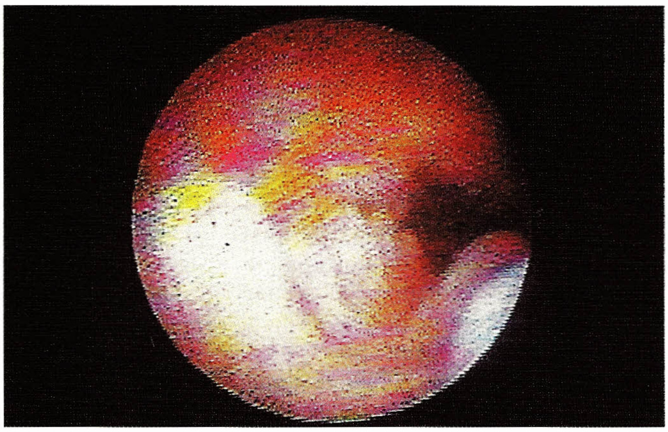

Figure 5. The bed of a removed ventricular catheter tip as viewed through a 1.2-mm scope.

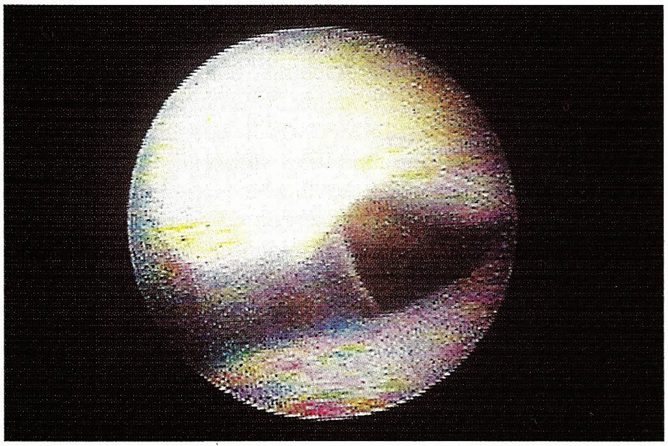

Figure 6. The septum pellucidum halfway through a septostomy procedure for trapped lateral ventricle. The 1.2-mm scope has been used to break down the septum with gentle pressure.

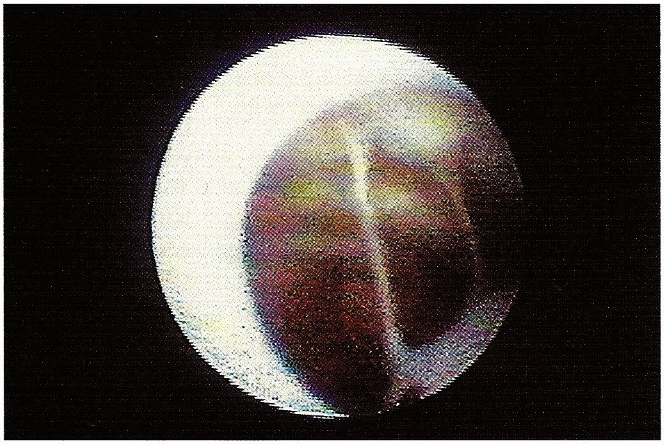

Figure 7. At the end of the procedure.

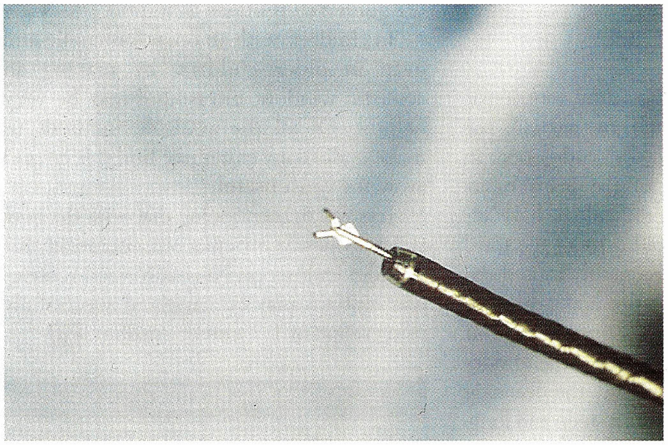

Figure 8. A biting forceps through a flexible scope.

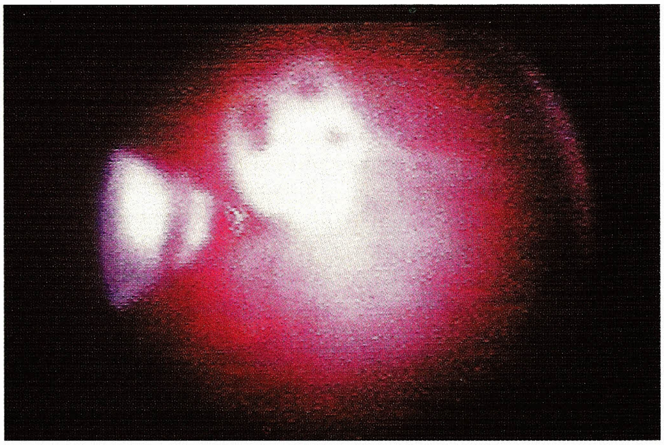

Figure 9. A YAG laser is used to perforate an arachnoid cyst protruding through the foramen of Munro.

tions at the moment for neuroendoscopy are: (1) put a hole in it; (2) take a bite of it. These options will obviously expand with the inevitable increase in types of endoscope-compatible instruments.

1. A hole may be put in something either by pushing with the scope itself (Figs. 6, 7) or by using an instrument. The instrument may be blunt, sharp, or use energy. A sound (e.g., 2 or 3 Fr.) Bugby Wire, may be used with or without monopolar current, one to dissect bluntly, the other to dissect with cautery. Laser energy is very useful in neuroendoscopy, the Neodymium:YAG system being able to deliver a precise amount of energy at a distance. Contact tip laser fibers capable of fitting down a relatively small working channel are readily available. More recently bipolar cautery has become available using electrodes either spaced a tiny distance apart at the tip of a wire or coaxial electrodes. It remains to be seen how useful these instruments will be, but they hold great promise to increase the control of energy placement at the working end of a neuroendoscope. The saline torch has been available for some years and is a powerful instrument for removing tissue.[4] It essentially is a monopolar device hooded by a ceramic material that heats a tiny jet of saline at its tip. The only objection to such an instrument (if indeed it is valid) is that, where trouble cannot be fixed and therefore must be avoided, it is perhaps too powerful.

2. Many biopsy forceps with forward-biting cups are available with flexible shafts of 0.7 mm and bigger (Fig. 8). Taking a biopsy is relatively straightforward; the problem will be the subsequent bleeding which may or may not be manageable with irrigation. Bleeding is the main problem with endoscopy. It obscures the field and makes further work impossible. While in the future adequate hemostasis may be attainable, for the moment the only treatment for bleeding is to avoid it.

3. While tumor removal is possible by multiple biopsy of a small lesion or with the saline torch, there is currently no endoscopic equivalent of a Cavitron. If one uses a large enough endoscope through which effective tumor removal instruments are to be used, one may as well do an open transcortical procedure with the microscope.

A few words about operating room setup may not be amiss. It is one of the more important things to remember that the screen—and almost all neuroendoscopy is performed with on-screen visualization—be easily visible to the surgeon without turning his or her head as this puts another and quite unnecessary level of complexity into the procedure. It is similarly obvious, but worth saying, that one should make sure that the camera has a good image prior to making a skin incision. The burr hole having been made and the CSF running out, there is no time to be fiddling with the camera or shouting for a scope that actually works.

Irrigation is usually provided for on a neuroscope system. Mechanical irrigation is probably best avoided. There are case reports of inadvertent intraoperative overinflation of the ventricular system because of unbridled mechanical irrigation.[5] We find manual irrigation by an assistant both simple and safe.

HYDROCEPHALUS

The most frequent application for neuroendoscopy is currently in the field of hydrocephalus.

Shunt Placement

Using a stylet scope placed inside a ventricular catheter, exact placement of the holes of the catheter may be achieved. Catheters are available which have an aperture in the tip, or a standard catheter may have the tip cut off or a slit put into it to allow the scope to protrude through the end. It has not been possible to prove that "optimal" placement of the tip results in lower revision rates, let alone that ventriculoscopic placement results in either of the above.[6,7] There is no question, however, that future revisions are easier with optimal placement and this is certainly the procedure on which to learn endoscopy. The most useful landmarks in the ventricle, in fact (besides pathology or pre-existing catheters) frequently the only useful landmarks, are the foramen of Munro (Fig. 9) and the choroid plexus. Whether one uses the anterior, posterior, or parietal approach, one should be able to appreciate these structures.

Encysted Hydrocephalus

Encysted hydrocephalus is frequently treated with a separate ventricular catheter. If there is a thin septum dividing a previously shunted area from a new area needing shunting, that septum can be disrupted either by pushing through it with a scope or by using a power source at the tip of the scope.[8] It goes without saying that one must have a very good idea of what is on the other side of the septum before one pushes or burns a hole in it. A good principle to bear in mind is that it is always easier to hit a large target from a small ventricle rather than the other way around. We have had good success using ventricular catheters with two or more sets of holes distally to drain more than one space; others find this one of the more unrewarding areas in neuroendoscopy.

Third Ventriculostomy

Whereas other procedures can be done more easily with the scope than without, this is the procedure nonpareil where one must use the scope. The procedure consists of placing an endoscope into the third ventricle of a patient, usually with late-onset aqueductal stenosis, and making a hole in the floor of the third, halfway between the mamillary bodies and the infundibulum. A shunt can be avoided in almost all patients with late-onset aqueductal stenosis; in other forms of hydrocephalus, a greater or lesser degree of success, depending on the type of hydrocephalus, may be achieved. This begs the question of how to make the hole. Many different techniques have been advocated, but none entirely obviates the risk of damage to the tip of the basilar and its perforators, which lie under the floor.[9]

The procedure was first described by Mixter, who used gentle pressure on the attenuated floor.[2] This is probably still the safest approach, using either the scope itself or a probe of some sort. The hole may be enlarged, if it is felt necessary to do so, by using a 2F balloon catheter passed through the scope.

Tumors

Any tumor presenting in the ventricular system may be biopsied or partially or wholly removed using the endoscope in combination with one of the instruments mentioned above. The difficulties have already been noted. Colloid cysts of the third ventricle are the most frequently touted endoscopically treated tumors and are often the "casus belli" in using a scope system.[10] It should be noted, however, that these tumors are not easy to remove and the learning curve in their removal is both steep and long.

POTENTIAL AREAS OF INTEREST

Spinal endoscopy has a long history, but only recently has interest been regenerated in this area. The most promising application appears to be in the anterior transthoracic approach to extradural lesions. Interest has been expressed in applying this technology to the field of tethered cord surgery. In spina bifida-related tethered cord, the procedures appear to be technically too difficult in most cases. Fatty filum surgery is feasible through a scope, though it remains to be seen if there is any advantage to doing this surgery endoscopically, as the open procedure is straightforward and, performed through a microscope, results in small skin and muscle incisions and requires no bone removal.

Frameless stereotaxis is currently being used to help in the basic problem of orientation intraoperatively. Conventional stereotaxis is somewhat cumbersome for using the scope, and all methods of stereotaxis currently available suffer the disadvantage of not being in real-time. This is particularly worrisome with regard to hydrocephalus procedures, since the brain may move considerably once fluid is removed. One may find oneself making decisions on the basis of scans obtained preoperatively, which no longer pertain to the intraoperative situation. In applications where millimeter accuracy is required (e.g., in deciding where to make the hole on a third ventriculostomy), stereotaxis cannot supersede direct visualization.

That being said, it is only a matter of time before useful intraoperative scanning becomes available; for some applications the currently available stereotaxis is appròpriate. If one wishes to approach small ventricles for whatever reason and needs to have a certain entry point to the ventricular system and a certain entry angle, CT-guided stereotaxis is helpful.

In children with an open fontanelle and even in older children by making an acoustic window, ultrasound may be very helpful. Of all the available methods to make endoscopy easier, we find this far and away the most useful.

It is worth mentioning that with the new stylet scopes, ventricular size no longer disqualifies endoscopy. Normally sized ventricular systems may be navigated successfully using scope of 1.2 mm or smaller. STI

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