Endoscopy in Neurosurgery

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SUMMARY
Introduction: There is currently no randomized controlled trial evidence of benefit for neuroendoscopy versus conventional neurosurgical treatment across a variety of indications. Methods: Medline review using search terms: neuroendoscopy, hydrocephalus, colloid cysts, cystic brain lesions, endoscopic pituitary surgery, spinal endoscopy. Results: The standard indications for neuroendoscopy are the treatment of hydrocephalus, intracerebral cysts and intraventricular tumors. The advantages of neuroendoscopy-assisted microsurgery as an adjuvant technique are self-evident. Whether endoscopy of the sellar region will gain is as yet uncertain. Endoscopic interventions on the vertebral column and spinal cord are now routine, but controversial. The endoscopic carpal tunnel surgery is established and widely practised. Discussion: The increasingly close links between neuroendoscopy and neuronavigation, and robotics, may bring promising developments. In future, virtual neuroendoscopy may aid the planning and execution of surgical interventions.

Key words: neuroendoscopy, hydrocephalus, intracerebral cyst, brain tumor, lumbar disc prolapse, carpal tunnel syndrome

Neuroendoscopy is a relatively new technique in neurosurgery that cannot yet be definitively judged on the basis of scientific evidence. Large-scale, randomized controlled studies and metaanalyses are currently in progress, but no conclusive findings have yet been reported regarding the potential advantages, for various indications, of this new technique over other, established ones.

In this article, neuroendoscopic techniques and their indications and results will be described and discussed in the light of the current literature. The literature search terms used were "neuroendoscopy," "hydrocephalus," "colloid cysts," "cystic brain lesions," "endoscopic pituitary surgery," and "spinal endoscopy."

History of neuroendoscopy
In 1910, Victor de l’Espinasse, a Chicago urologist, performed an endoscopic operation on the ventricular system of a neonate with hydrocephalus. He is therefore considered the father of neuroendoscopy. It was not until February 6, 1923, however, that William J. Mixter, a neurosurgeon, performed the first endoscopic ventriculostomy in a child with congenital obstructive hydrocephalus. The instruments available at that time were not very suitable for use in the brain, and the endoscopic treatment of hydrocephalus was thus only rarely practiced.

The situation changed in the latter half of the 1980’s with the development of miniaturized endoscopes and endoscopic instruments (1). Today, endoscopic procedures for certain well-defined indications belong to the standard repertoire of neurosurgical operative techniques (2).

Instruments and planning of the neuroendoscopic approach
Neuroendoscope
Many different types of neuroendoscope with good optical properties are now available, and little improvement seems to be needed in this area (3). A neuroendoscope should have two working channels to enable the surgeon to work with both hands (as in conventional, non-endoscopic microsurgery), as well as a channel for irrigation and suction. A compromise must be struck, so that the parenchymal trauma due to the insertion of the device is minimized.
while the endoscope simultaneously remains optimally manipulable for surgical purposes. The standard types of neuroendoscopes today have a diameter of 3 to 6 mm. Diameters greater than 8 mm are not acceptable, because the use of such instruments affords no advantage over conventional microsurgery. Intraoperatively interchangeable endoscopes with different viewing angles, i.e., angulated optics, must be used to enable inspection of the operative field from a variety of perspectives (figure 1).

A special problem may arise in neuroendoscopic procedures on neonates or infants. Large-diameter adult endoscopes should not be used in such patients, as their use promotes the development of a cerebrospinal fluid fistula to the skin along the trajectory of insertion of the endoscope through the brain parenchyma. It has been found to be safer to use pediatric endoscopes of diameter 2–3 mm with two working channels and high-quality optics.

Ultra-thin endoscopes have been designed and put to use as microsurgical operating instruments for endoscopically assisted microsurgery, e.g., as "seeing dissectors" in cerebral aneurysm surgery. Such instruments enable the neurosurgeon to see around corners in the operative field. Obviously, endoscopes that are designed for this purpose can be kept very thin, as they do not need to have any working channels (4).

**Operative instruments**

At the beginning, there was no uniform instrumentation set for neuroendoscopy, but it has now been clearly established which instruments are minimally required for such procedures:
bipolar cutting and coagulating microinstruments (figure 2), microscissors, and grasping and biopsy forceps (5).

**Planning the neuroendoscopic approach**

The precise, three-dimensional planning of the neuroendoscopic approach, i.e., the determination of the burr hole site, approach trajectory, and target, can be carried out either with stereotactic neurosurgical technique (6) or with the aid of neuronavigation (7). The advantage of neuronavigation over stereotaxy is the surgeon’s greater freedom in the manipulation of the endoscope when it does not need to be attached to a stereotactic frame. A combination of neuroendoscopy and neuronavigation is currently the operative standard (figure 3). Neuronavigation is unnecessary in the endoscopic treatment of severe hydrocephalus, because entering the ventricular system is unproblematic and adequate intraoperative orientation can be acquired from the visible anatomic landmarks.

So-called virtual ventriculoscopy (8) is a new imaging technique that is currently in the process of development. It enables three-dimensional planning of neuroendoscopic procedures so that they can be “performed” preoperatively in a virtual environment (figure 4).

**Indications for intracranial endoscopic procedures**

The indications for neuroendoscopic operations have been standardized in the last few years. In general, neuroendoscopy is used for procedures in preexisting or pathologically formed cavities in the central nervous system (9).
Hydrocephalus
In the treatment of hydrocephalus, neuroendoscopic techniques can be used to reconstitute or recreate the natural pathways of cerebrospinal fluid (CSF) flow, and thereby to obviate the need for the insertion of a shunt system (foreign body in the brain). Endoscopic third ventriculostomy (ETV) has come to new life as a concept for the treatment of occlusive hydrocephalus (10) because of the complications commonly associated with the implantation of shunts to treat hydrocephalus, including shunt malfunction, thrombosis, infection, over-drainage, and slit-ventricle syndrome. In occlusive hydrocephalus, the CSF resorption mechanisms remain intact, and “internal shunt methods” such as ventriculostomy can, therefore, be used (box).

Recent publications have shown that patients whose hydrocephalus has been treated with shunts and who have suffered multiple episodes of shunt malfunction can be successfully treated with neuroendoscopy, so that they can do without a shunt from then onward. Patients considered to be at elevated risk of complications from surgical shunt revision, including those with post-hemorrhagic and post-meningitic hydrocephalus (14), should have an endoscopic procedure instead. Since the advent of endoscopy, the old clinical rule “once a shunt, always a shunt” thankfully no longer applies.

In special cases of aqueductal stenosis, particularly when there is an isolated fourth ventricle, a so-called aqueductoplasty can be performed. In this procedure, the pathway of CSF flow is reconstituted by the endoscopic insertion of a stent from the third to the fourth ventricle, and the implantation of a shunt is thereby avoided. Aqueductoplasty is thus an alternative to ventriculoplasty when the latter would be technically difficult (15). Not all types of hydrocephalus are amenable to neuroendoscopic treatment. There is as yet no predictive test for the success of endoscopic ventriculostomy. The best outcomes to date have been documented for occlusive hydrocephalus due to tumor-associated aqueductal stenosis or fourth ventricular displacement, followed by idiopathic aqueductal stenosis. The success rate in post-meningitic and post-hemorrhagic hydrocephalus is markedly lower, as it is, too, in normal-pressure hydrocephalus (NPH). Gangemi et al. (16) treated 25 NPH patients with endoscopic third ventriculostomy and achieved a success rate of 72%; in particular, these patients’ gait disturbance was improved.

**Box**

**Facts on the neuroendoscopic treatment of hydrocephalus**

- A stoma in the floor of the third ventricle should be between 4 and 6 mm in diameter, depending on the anatomical situation.
- The rate of closure of ventricular stomata is ca. 2%. A closed stoma can often be reopened in a second endoscopic procedure (11).
- The long-term success rate of third ventriculostomy (i.e., shunt independence) lies between 70% and 90% (12).
- The morbidity and mortality of neuroendoscopic treatment, and the rate of stoma closure, are no higher in infants and young children than in adults.
- The etiology of hydrocephalus is the most important factor guiding the decision to treat with neuroendoscopy. In occlusive hydrocephalus, third ventriculostomy is always indicated (13).
- Patients who were initially treated with a shunt and subsequently had multiple shunt-related complications can be treated with neuroendoscopy.
Intracranial cysts

Intracranial cysts are particularly suitable for neuroendoscopic treatment. Colloid, arachnoid, and pineal cysts can be endoscopically aspirated and fenestrated or removed. For the treatment of cystic craniopharyngiomas, dysontogenetic tumors, gliomas, and metastases, neuroendoscopy can be used in combination with microsurgical resection, radiotherapy, and adjuvant chemotherapy.

Colloid cysts

Colloid cysts, because of their intraventricular location, are a classic indication for neuroendoscopy (17). Patients with symptoms of occlusive hydrocephalus are treated operatively. For asymptomatic patients, an operation is indicated when the cyst is large enough to threaten an acute occlusion of the foramen of Monro, which would cause acute occlusive hydrocephalus. A preventive operation is justified in view of the reports of sudden death in previously asymptomatic patients with colloid cysts (18).

The postoperative results of neuroendoscopic surgery for colloid cysts are at least as good as those of microsurgery in terms of morbidity, mortality, and recurrence rates.

Figure 5: Low-grade astrocytoma in the posterior portion of the third ventricle.
(a) The T2-weighted preoperative MRI scan shows that the tumor is causing obstructive hydrocephalus;
(b) Endoscopic biopsy of the tumor;
(c) Immediately after biopsy, a third ventriculostomy is performed to treat the occlusive hydrocephalus;
(d) The postoperative MRI shows a prominent flow void at the floor of the third ventricle, indicating flow of CSF into the interpeduncular fossa.
Among 32 patients with colloid cysts whom the authors treated by neuroendoscopic surgery, the majority had a subtotal removal of the cyst, yet only 1 patient had a recurrent cyst after 12 years of follow-up. It should be noted, however, that only a few endoscopically treated patients have been followed postoperatively for more than 10 years. It therefore remains possible that endoscopic colloid cyst evacuation and partial resection of the cyst wall actually does lead to a higher recurrence rate than complete microsurgical cyst resection.

Arachnoid cysts
Intra-arachnoidally located cysts filled with CSF are called arachnoid cysts. They can be found intracranially at many different sites. Most of these cysts are large cavities in the immediate vicinity of the ventricular system or the intracranial cisterns and are therefore well suited to a neuroendoscopic approach. This is particularly true of so-called suprasellar arachnoid cysts.

An operation is indicated when the arachnoid cyst is symptomatic, i.e., when it elevates the intracranial pressure, causing headache or other neurological symptoms and signs (19). Neuroendoscopy can be used alone or in combination with conventional microsurgery.

The postoperative results of endoscopic surgery for arachnoid cysts are comparable to those of conventional microsurgery. Approximately 75% of patients benefit from the operation. A reduction of cyst size is not a prerequisite for clinical improvement. The most important factor is the linkage of the cyst to the draining CSF pathways so that the intracranial pressure can be normalized.

Solid intraventricular tumors
Solid intraventricular tumors, too, can be treated with neuroendoscopy. Such tumors are preferably biopsied with neuroendoscopic guidance, rather than “blindly” by stereotaxy. Biopsy under direct vision is particularly advantageous in the area of the foramen of Monro, as well as for pineal tumors in the posterior portion of the third ventricle. The operative approach can be chosen to spare ventricular vessels and functionally important structures, because endoscopy, unlike stereotaxy, offers the neurosurgeon a direct visual check. If the tumor is causing occlusive hydrocephalus (e.g., because of its location in the posterior portion of the third ventricle), a third ventriculostomy can be performed at the same sitting, or, alternatively, a stent can be inserted between a lateral ventricle and the third ventricle, or between the third and fourth ventricles (figure 5).

The likelihood of complete tumor resection via neuroendoscopic surgery is a function of tumor size. Neuroendoscopy is excessively time-consuming if the tumor exceeds 2 cm in diameter.

Neuroendoscopically assisted microsurgery
Endoscopes can be used as auxiliary tools in microsurgery, particularly in operations for cerebrovascular aneurysms, microvascular decompression, and lesions of the cerebellopontine angle. Endoscopes of different designs are available for different uses. They provide the important ability to look around corners or behind the lesion in question. In aneurysm surgery, for example, the optimal position of the clip can be confirmed, while in microvascular decompression the vascular loop impinging on the trigeminal nerve can be inspected from all sides.

Endoscopic pituitary surgery
Guiot, in 1962, was the first to use an endoscope in pituitary surgery (20). In recent years, the use of endoscopy in adenoma resection has markedly increased but has not yet become standard. The operative approach is simple and fast and has few complications. By now, adequate instrumentation is available to allow the neurosurgeon to work effectively through a narrow opening. It is important, however, that the neurosurgeon performing endoscopic pituitary surgery should also be well-versed in conventional transsphenoidal microsurgery, so that he or she can switch to the other technique if anatomical or other technical difficulties are encountered. The literature does not yet provide any long-term results of endoscopic adenoma resection; therefore, this technique cannot yet be definitively assessed. The following conclusions can be drawn, however, from the initial published results and personal communications (21):
endoscopic pituitary surgery is associated with
- shorter operative times,
- reduced operative trauma,
- rarer intra- and postoperative complications,
- and a shorter postoperative period of bed rest.

Neuroendoscopic spinal procedures
Many different techniques in the category of minimally invasive endoscopic spinal surgery have been developed in recent years, and some have already been described in this journal. Thus, the development of neuroendoscopy now means that Krämer's assertion, made in 2002 (22), is no longer true: "If the anulus fibrosus has been perforated, sequestrated material is pressing on the nerve root, and corresponding neurological manifestations are present, an open operation is necessary." A number of endoscopic systems are now available that enable the removal, through the intervertebral foramen, of subligamentous, freely sequestrated, intraforaminal, mediolateral, and medial disk fragments, as well as fragments that have become cranially or caudally displaced within the spinal canal. In certain situations, e.g., when there is a displaced fragment and the site of perforation of the anulus fibrosus is covered, the intervertebral space need not be completely emptied of disk material after the prolapse is removed. Removal of the fragment alone and the site of perforation of the anulus fibrosus is covered, the intervertebral space need not be completely emptied of disk material after the prolapse is removed. Removal of the fragment alone is considered adequate treatment and has been shown to yield comparable results (23). A further endoscopic method for the treatment of disk prolapses and spinal canal stenosis is so-called microendoscopic discectomy (MED), which makes use of a posterior or posteromedial approach through the interlaminar window.

It is not yet clear whether endoscopic spinal techniques yield better long-term results than conventional microsurgery.

Endoscopic carpal tunnel surgery
Endoscopic carpal tunnel surgery is now part of standard practice and is used as an alternative to conventional macrosurgical techniques. A number of different companies now offer complete endoscopic surgical kits for carpal tunnel surgery, some of which are quite expensive. Surgeons can also put together all of the necessary apparatus for carpal tunnel surgery more cheaply by themselves. Two kinds of approaches can be used for endoscopic surgery in the palm of the hand: the uniportal approach (insertion of the endoscope proximal to the wrist joint) and the biportal approach (second skin incision).

Endoscopic splitting of the flexor retinaculum is indicated in all patients with clinically and electrophysiologically documented carpal tunnel syndrome. The procedure is contraindicated if the carpal tunnel is too narrow or if the patient has previously undergone carpal tunnel surgery on the affected side.

Although few data from randomized studies are available to date, and although the use of endoscopy for carpal tunnel surgery currently faces criticism (25) because of a higher complication rate than that associated with the traditional, open technique, endoscopy in this area does seem to provide the following advantages:
- a better cosmetic result,
- earlier use of the operated hand,
- and less postoperative pain.

In summary, neuroendoscopy is already a recognized technique for the treatment of many different lesions affecting the nervous system. In the next few years, the advantages and disadvantages of neuroendoscopy in comparison with older, established neurosurgical techniques will need to be critically assessed for a number of the indications for which it is currently performed.

Conflict of Interest Statement
Prof. Hellwig developed the Hellwig ventriculoscope in collaboration with Rudolf Medical GmbH, a medical technology company. The other authors declare that they have no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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