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Editorial

Future of endoscopy in neurosurgery

What is the future of endoscopy for the brain? It is not easy to answer such a question mainly because of its recent explosion during the last decade after a century of step-by-step advances. Is it possible to reach new goals? Is it possible to perform or to improve every neurosurgical procedure by means of endoscopy? To explore the potential for future development, it is advisable to define endoscopy and to determine the justifications of its use on the brain to be able to foresee the future of the instrument itself and of its applications.

1. Principles of endoscopy

The endoscope is a tool that makes it possible to see and perform gestures under visual control in anatomical cavities not accessible at first glance. Endoscopy, however, has particular specificities that condition its use:

1. The endoscopic field of vision is a cone whose top is located at the distal end of the tool and whose axis is in the prolongation of the axis of the endoscope itself or can vary from 0° to 120° according to the obliqueness of the distal lens of the rigid endoscopes. All that is beyond the cone is thus hidden by definition. An added fiberoptic cable brings the light from an external source. The intensity of the light and, thus, the clearness of the picture depend on the intensity of the source, on the clearness of the medium crossed by the light (air, more or less translucent liquid), and on the reverberation of the light on the walls of the cavity (the whiter they are, the clearer the image will be). Lastly, the endoscope provides a bidimensional image, although the lack of stereoscopic view can be overcome with training by understanding the value of all the lights and shadows coming to our vision and getting multiple landmarks in the course of each surgery.
2. The use of surgical instruments is limited by the possibility of their control and their obliqueness compared to the axis of vision:
   (a) Within the endoscopic cone of vision, the distal end of the instruments and their movements are under visual control, but not their introduction nor their proximal movements. Furthermore, the endoscope has to be held by the hand, which allows the use of only one other tool in bimanual mode, unless the endoscope is held by a self-retaining holding device or by an assistant. For delicate manipulations, a reliable fixation is advocated to enable bimanual dissections, just as surgeons use to do under the microscope, or the surgeon can work in close cooperation with his coworker, with the latter handling the scope—like a pilot and a navigator in a rally race. In addition, the lack of stereoscopic view can be overcome with training.
   (b) The obliqueness of the instruments, one compared to the other or to the axis of the endoscope, depends on their entry point:
      - if the cavity is open outside, the obliqueness of the tools depends on the diameter of the entry point (eg, diameter of the nostril for transsphenoidal surgery or diameter of the craniotomy) and on the depth of the cavity itself;
      - In closed cavities, like the cerebral ventricles, the instruments can only be coaxial and can be introduced via an operating channel, unless a second entry is created, as in biportal accesses.
3. The cavity into which the endoscope is introduced must have a diameter larger than it to permit its movement without risk of lesion to the walls.

2. Application of endoscopy to the brain

The brain has natural cavities filled with cerebrospinal fluid, ventricles, and subarachnoid spaces, which are not wide enough for endoscopic navigation. In pathologies widening these spaces, one can use an endoscope, such as for hydrocephalus and arachnoid cysts. In the brain, because of the absence of obliqueness of the axis of the instruments compared to the axis of the endoscope (except for biportal accesses which are rather complex) and the limited character

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of the movements of the scope, the instrumental possibilities are limited: a forceps can grip a structure, biopsy a small fragment, or elevate a structure from another. Probes can perforate a membrane, coagulate or aspirate the contents of a cavity; scissors can cut a structure, only if it is orientated in a perpendicular plane. Nevertheless, in almost all cases, these tools are used only one at time, with time between each action necessary to withdraw the first instrument and introduce the following, and on very small structures. This explains why endoscopy has found its main applications for third ventriculostomy, in the treatment of obstructive hydrocephalus, for marsupialization of arachnoid cysts, for the treatment of colloid cysts of the third ventricle (puncture or removal), for the removal of small intraventricular tumors, and in the biopsy of some intra- and paraventricular lesions.

The transsphenoidal approach has been shown to be a procedure tailored to the possibilities of the endoscope: the existence of a natural cavity like the sphenoid sinus, a natural way toward the sella to be just slightly enlarged. Almost a century of surgery on the pituitary area has favored the diffusion of endoscopy in the sellar region for the removal of pituitary adenomas and other lesions of this area and has changed the indications for treatment of CSF leaks of the anterior skull base, which are currently managed by means of different transnasal endoscopic procedures.

Endoscopy can also be used in newly created "cavities" like tumor cysts or cavities formed by intracerebral hematomas. Nevertheless, in such cases, the quality of the vision will be decreased because of lower transparency of the crossed mediums (xanthochromic or hemorrhagic liquids) and of the decreased reverberation of the light on the walls (often hemorrhagic).

During microsurgical operations, endoscopy provides an undeniable help in bringing additional light and vision in some corners, mainly in pterional, supraorbital, or pontocerebellar angle approaches. It is the principle of the endoscope-assisted microsurgery. Although the major part of surgery is done under the microscope, certain steps of the procedure are carried out under endoscopic view, thus combining the advantages of the microscope with those of the endoscope. The microscope provides a binocular view with superb resolution. However, when operating in depth, especially in narrow surgical corridors, there is a considerable decrease in light intensity, and the depth of field is low under high magnification. Furthermore, lesions that are not visible in a straight line cannot be explored. The endoscope brings the eye of the surgeon close to the region of interest, provides a perfect illumination in the depth, and has a wide angle of view (30°, 45°, 70°, 120°) as well as a large focus range. With angled scopes, areas that are not visible in a straight line can be inspected and managed using dedicated instruments without drilling or retraction. When operating under endoscopic view, just "around the corner," special angulated instruments like curettes, dissectors, and bipolar forceps are required. Care has to be taken when inserting or removing these instruments into/from the depth of the surgical field to avoid damage to neurovascular structures that are not under direct view of the endoscope. In endoscope-assisted microsurgery, rigid rod lens optics should be used because the image quality is far superior. Care should be taken in prolonged dissections under endoscopic view because the tip of the scope may become hot, and the surgeon has to make sure that the tissues are not drying out.

The endoscope-assisted technique has turned out to be useful in skull base tumors, such as vestibular schwannomas (removal under direct visualization in the distal part of the internal auditory canal and to check the completeness of tumor removal), meningiomas of the skull base (in their remote corners or where hidden behind neurovascular structures), and epidermoids (often spreading in the subarachnoid space of the middle and posterior fossa). When dealing with large tumors, the intrasellar and intraventricular parts of the lesion not visible in a straight line with the microscope can be visualized and removed under endoscopic control.

In aneurysm surgery, in some caudally and medially arising aneurysms of the proximal internal carotid artery, the entire aneurysm cannot be visualized. In addition, in aneurysms of the basilar tip area, the endoscope provides a panoramic image of the adjacent branches and perforators. In most aneurysms, the endoscope is simply used for inspection before and after clipping.

In vascular compression syndromes, such as trigeminal neuralgia and hemifacial spasm, the compression site is mostly ventrally located, which means behind the nerve, from the surgeon's point of view. Although the compressing vessel can be moved away from the entry/exit zone without significant manipulations of the nerve, the compression site may not be directly seen, and the endoscope is very beneficial in the detection of hidden compression sites.

3. Future of cerebral endoscopy

The future of endoscopy for the brain can be targeted in 2 directions:

1. Extension of current indications:
   Many publications report on the success of third ventriculostomy in the treatment of obstructive hydrocephalus. Its advantage consists of the absence of implanted devices with their well-known complications, for a clinical benefit comparable with the shunt procedure. However, there are still many neurosurgical centers in the world where this technique is not applied; hence, there is still a margin of progress to the point where this technique will be applied in each case of obstructive hydrocephalus, whatever the obstruction is, from the aqueductal area to the foramen of Magendie. Moreover, the same tool that can be used to treat a great number of patients

without the need of a single use device like the shunt is of undeniable interest. Besides obstructive hydrocephalus, some publications report on interesting results of this technique for chronic noncommunicating hydrocephalus. If this fact will be confirmed, one can imagine future consequences not only on the number of treated patients but especially on the improvement of knowledge on hydrocephalus.

Colloid cysts are a subject of controversy. Nevertheless, publications are accumulating to confirm the interest in using endoscopy for the treatment of this pathology. The same consideration could be applied to the endoscopic marsupialization of suprasellar arachnoid cysts. Probably, other current indications will remain marginal in the number of treated cases without modification of their indication (marsupialization of the temporal cysts or from other localizations, tumoral biopsies, ablation of lost catheters, marsupialization of complex hydrocephalus).

The advent of the endoscope in pituitary surgery has recently brought modifications on the standard transsphenoidal approach that allow additional exposure of around-the-sella areas used for various skull base lesions and endoscopic endonasal approaches for extrasellar compartment from the planum sphenoidale up to the craniocervical junction. Indeed, today, cases of suprasellar, retroclival, and intracavenous lesions treated by means of transsphenoidal technique, either endo- or micro-assisted procedures, are reported with growing frequency and encouraging results.

In our opinion, the endoscope-assisted microsurgical technique, introduced by Perneczky in the early 1990s will gain a well-established place in the neurosurgical armamentarium. Neurosurgeons should be able to use the advantages of both the microscope and the endoscope as needed for the benefit of their patients. There should be no competition between the 2 optical systems but rather close collaboration. It is important to simultaneously provide both the microscopic and endoscopic image to the surgeon.

2. Instrument development: We expect progress in 2 directions.
    - Better vision by the improvement of the resolution of video cameras (eg, high definition television) and by means of either 3-dimensional scopes, adding a sense of depth similar to that of the microscope that most neurosurgeons are familiar with, or with the so-called chip stick technology (a small rigid fiberscope held like a suction cannula with a chip at its distal tip);
    - Instrument development to better manage what the endoscope allows to be viewed. To this goal, many different tools can be realized and/or improved, first of all those concerning coagulation or direct control/touch with the vessels;
    - Progressive miniaturization is also important for the development of other instruments used in endoscopic surgery. Design of miniaturized instruments does not mean less functionality, but, on the contrary, it means more versatility, safety, and utility.

4. Conclusion

We should always keep in mind that the endoscope is an instrument and that its limitation is predicated by recognition of its correct indication and use for each pathologic condition. We cannot emphasize enough the indications, even if in the process of progress, continuous adjustments are necessary. The equation "endoscopy = no limits" does exist as the target is moved further, step-by-step, by overcoming the obstacles to reach the best result for each patient. To this purpose, critical evaluation and participation in the scientific community debate are needed to validate one's own ideas and to recruit new ones. Again, work, research, and communication are the keys for progress.

To imagine the future of endoscopy for the brain, we need to consider its replacement in the long term. For performing surgery, it is necessary to see in real time and to use tools in the most precise way, which today, endoscopy allows even with some limitations. Virtual imaging, if reactualized within a time compatible with action, one day might replace endoscopy as it reflects images through an optical system. Thanks to stereotaxy, neurosurgery knows how to precisely guide a tool in a given space. If the hand remains the engine of the action, it could be stabilized and guided in this up-to-date virtual and stereotaxic space by a robot-like system. This could be the real and ultimate future of endoscopy. There may come a time when we may not need neuroendoscopy. Until then, we must forge ahead to continuously improve the techniques for our patients.

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