Complication Avoidance in Minimally Invasive Neurosurgery

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• Complication • Endoscopic • Outcome • Avoidance

Although minimally invasive neurosurgery (MIN) holds the potential for reducing the approach-related impact on normal brain, bone, and soft tissues, which must be manipulated in more conventional transcranial microneurosurgery, the techniques necessary to perform minimally invasive, yet maximally effective neurosurgery place significant demands on the surgeon because in many ways the more limited exposure creates a number of unique ways these operations can go wrong. Safe and effective MIN requires the conscious institution of specific alterations to the surgeon's usual operative case flow, which are designed to make specific well-known mistakes impossible or at least very unlikely. Thus, it is important for the aspiring MIN surgeons to learn from the mistakes of their predecessors and to institute patterns of behavior that prevent a repetition of these mistakes. This article provides practical information regarding known pitfalls in intraventricular and transcranial neuroendoscopic surgeries and provides practical methods to reduce the incidence of these complications to the lowest rate possible.

PITFALL #1: LACK OF NECESSARY EQUIPMENT OR EQUIPMENT FAILURE

This pitfall category roughly encompasses a large number of potential mistakes, all of which are significantly problematic and avoidable. It is important to view endoscopic surgery in the model of the airline industry, in that the beginning of each procedure should involve a systematic and stereotyped evaluation of the equipment needed to perform the procedure in question. Most importantly, the presence of each endoscope needed to perform the planned procedure needs to be confirmed, and the function and image quality of these endoscopes need to be evaluated. Ideally, this evaluation should be performed before the induction of general anesthesia but certainly must be done before skin incision. Further, all working cannulas or sheaths and all introducing devices need to be present and confirmed to be correct for the endoscopes in use. If specifically instrumentation (eg, monopolar cautery, graspers, suction tubing) is needed, it should be confirmed that it is present and functioning and that it will fit down the working channel of the endoscope used. If image guidance is to be used, it should be confirmed to be appropriately registered and to have image probes or other device adapters appropriate for the planned case.

In addition, it is important that the instrumentation is confirmed to be setup and working appropriately before skin incision. The foramen of Monro is not the correct time and place to troubleshoot problems with the monitors, incorrect up-down orientation with the endoscope, and malfunctioning irrigation channels. A systematic checklist approach is the key to avoid these frustrating errors.

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PITFALL #2: INAPPROPRIATE PREOPERATIVE PLANNING

Given the keyhole emphasis of MIN, MIN exposures tend to expose less and are thus less flexible than larger exposures. Openings are targeted to the pathology in question and are not robust to large inappropriate deviations from the ideal trajectory. Hence, it is important to spend more time with this approach than one would spend with a larger approach, considering the implications of specific aspects of the intended trajectory. Although some procedures (notably third ventriculostomy) can be performed using stereotyped entry points, most procedures require a thoughtful case-by-case assessment of the individual lesion being treated and its relationship to critical normal structures. Although planning these cases becomes more intuitive with experience, image guidance can be invaluable to those less experienced with MIN. For complicated intraventricular or intracranial lesions, the use of image guidance to plan an idea trajectory and to adhere to this plan is indispensible, and an excellent image registration should be viewed as a critical part of technical success.

PITFALL #3: GETTING LOST

Second only to beginning the procedure without the appropriate equipment, getting lost is the greatest sin of minimally invasive intraventricular or intracranial surgery, and without conscious efforts to avoid getting lost, it is an easier state to achieve than one would initially think is possible. An inaccurate or inappropriate understanding of the anatomy visualized can provide the unwary surgeon with a false sense of what areas are safe and what areas to avoid, prompting inappropriate actions, with potentially devastating results. A thorough familiarity with the anatomy obtained through dissections and experience obviously lowers the risk of getting lost, especially when combined with image guidance.

There are several common regions encountered during ventriculoscopy that even those familiar with the relevant anatomy can misinterpret, if not aware of these possible mistakes. One well-known error is unknowingly entering the contralateral lateral ventricle, which if not recognized can cause the surgeon to inappropriately enter the wrong foramen of Monro, causing traction and potential injury to both fornices. Another error is mistaking the cerebral aqueduct for the infundibular recess of the third ventricle. Such a misinterpretation can cause the surgeon to perform a third ventriculostomy, just posterior to the mamillary bodies (which is interpreted as being anterior to the mamillary bodies), with devastating injury to the midbrain and/or basilar artery. Hence, it is critical that after gaining ventricular access with the endoscope the surgeon survey the anatomy carefully before making any definitive maneuvers. The choice of correct trajectory, the appropriate confirmation and maintenance of a correct up-down orientation of the endoscope, and the use of image guidance are also important for avoiding these kinds of mistakes. However, the importance of a slow and deliberate assessment of the orientation provided is essential to avoid getting lost.

PITFALL #4: INAPPROPRIATE POSITIONING

Appropriate patient positioning for MIN goes hand in hand with preoperative planning. Although some procedures can be performed using stereotyped room arrangements and patient positioning, it is important to consciously assess the effect of the planned position in the context of the planned trajectory. If the planned position makes the ideal trajectory awkward, then the risk of deviating from this trajectory is higher, thus increasing the possibility of obtaining problematic or disorienting anatomic views as described earlier.

Further, for transcranial endoscope-assisted procedures, good patient positioning can maximize gravity brain retraction and obviate the need for physical brain retractors, which is doubtlessly better for the patient.

PITFALL #5: FAILED ATTEMPTS TO ACCESS THE VENTRICLE

Most endoscopes used in intraventricular endoscopy are much larger than ventricular catheters that neurosurgeons use for cerebrospinal fluid diversion procedures. It is hypothesized that larger diameter instruments cause greater tearing of white matter tracts than ventricular catheters. This feature makes inappropriate passes into the thalamus, internal capsule, brainstem, and basal ganglia a potential devastating complication of misguided attempts to enter the ventricle with the endoscope. Although good preoperative planning and the use of image guidance can reduce this risk, they cannot eliminate it because some brain shift is inevitable upon dural entry. It is critical to first tap the ventricle with a smaller gauge cannula or ventricular catheter to ensure that the planned trajectory is into the ventricle and that the anatomy is roughly as anticipated.

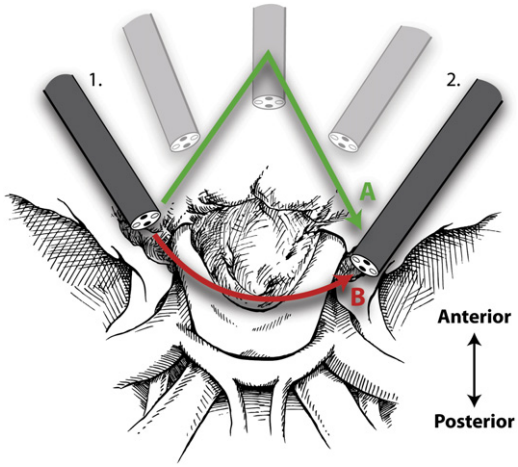

Fig. 1. A comparison of methods for redirecting the position of the endoscope from position 1 to position 2. The trajectories for the incorrect (B) slashing maneuver and correct (A) fencing maneuver for lateral movement of the endoscope are compared to highlight the potential consequences of the slashing maneuver in an anatomically critical position.

PITFALL #6: INAPPROPRIATE MOVEMENT OF THE ENDOSCOPE

Learning to avoid this complication requires a conscious effort to alter one's instinct to decide that a nearby structure in the peripheral portion of the field of endoscopic vision is of interest and to swing the endoscope laterally to visualize this structure. The risk of such maneuvers is indicated in **Fig. 1**. As demonstrated, these lateral sweeping maneuvers risk injuring or tearing all structures within the angle subtended by this sweeping motion. MIN surgeons need to consciously train themselves to maneuver the endoscope laterally using a fencing motion as opposed to a slashing motion (see **Fig. 1**), which is best perfected with practical exercises on cadavers.

PITFALL #7: FAILURE TO APPRECIATE THE ENDOSCOPE'S BLIND SPOT

One principle advantage of the endoscope is its ability to place the light and view sources as close to the area of interest as possible, thus limiting interference from more proximal overlying structures. One of its most dangerous features is that when the endoscope is placed close to the region of interest, the surgeon's ability to appropriately visualize much of the pathway between the skin and the target becomes minimal (**Fig. 2**A). This trait creates the potential for instruments to unknowingly injure important structures on the way in, if blindly introduced. MIN surgeons must consciously train themselves to remove the endoscope with the insertion of each new instrument and to follow the instrument into the field under direct endoscopic visualization.

A corollary of the endoscopic blind spot is the potential for the endoscope to inadvertently strike or cause pressure injury to unseen structures behind it (see **Fig. 2**B). This potential is most important during transcranial endoscopic surgery because endoscopic visualization of deeper intracranial structures can place critical structures, such as the optic nerve, in the blind spot where it can be injured by the endoscope that is out of view. This injury can be avoided by continuous visual monitoring of the endoscope shaft's location by the surgical assistant who observes the endoscope through the microscope and prevents contact with important structures, such as the optic nerve.

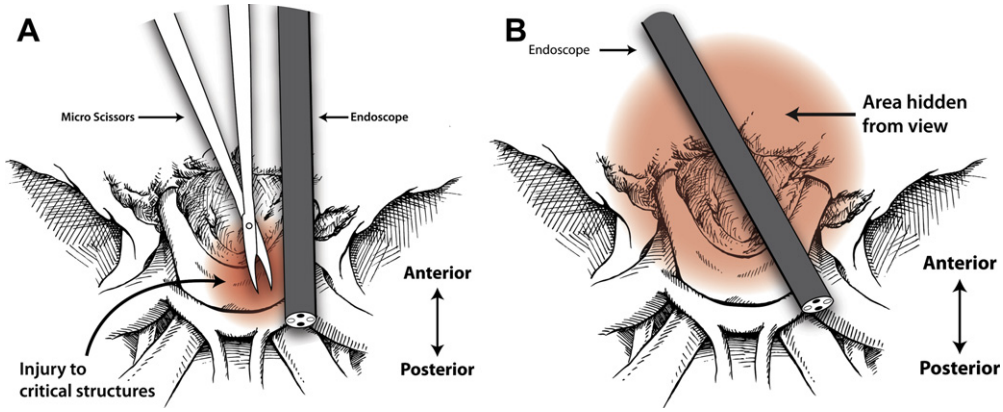

Fig. 2. The blind spot of the endoscope. (*A*) The risk of blindly introducing instruments without direct endoscopic visualization. (*B*) The risk of not being aware of the position of the endoscope shaft.

PITFALL #8: BITING OFF MORE THAN YOU CAN CHEW

Like microsurgery, endoscopic neurosurgery is a skill set which improves with use, and there is a learning curve. The views are often unfamiliar, and disorientation is easier than with the microscope, especially during the transition from the microscope to the endoscope. The methods for dealing with problems such as bleeding in an endoscopic approach are different from those in microsurgery, and many neurosurgeons feel less in control at first. Further, many good habits such as using correct techniques for moving the endoscope and introducing instruments must be consciously adopted and reinforced through practice. As endoscopy is introduced at an institution, operating room staff similarly face their own learning curve, thus learning to set up these cases effectively.

Given these facts, it is important that neurosurgeons begin their use of endoscopy in a deliberate and measured fashion, progressing from simple to progressively more complex cases. This is especially true with cases involving a multidisciplinary team-based approach (such as endonasal cases), which add the additional need to learn the tendencies of the cosurgeon and to become familiar with the entire case as a whole. Learning to progress in MIN requires a conscious and deliberate plan for progression, as well as continuous assessment and refinement of techniques.