Complications of Endoscopic Third Ventriculostomy

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Introduction

Justifiably, endoscopic third ventriculostomy (ETV) is considered the greatest breakthrough in the management of hydrocephalus since the introduction of Silastic shunts. Among selected patients, the procedure can render over 70% of children shunt-independent [13, 27, 28]. More recently, however, the procedure has been the focus of scrutiny, with an increased number of reports showing long-term failures and serious complications [1, 4, 8, 11, 16, 17, 23, 25]. Indeed, it is felt among the endoscopic neurosurgical community that the real complication rate may be higher than those published. Although this chapter will review both the well-known and the rarer complications of ETV, complication avoidance will constitute the main body of the text.

Complications Specific to ETV

Bradycardia and Asystole

This common intraoperative complication has been recognized for many years [7, 12]. It was documented in one of the first large series of ETV [27] and identified as a not uncommon occurrence that should be anticipated and detected by turning up the volume of the cardiac monitor. It can occur at any time during manipulation of the third ventricle. It may occur when the scope is introduced, when irrigation is used, or when pressure is placed on the floor (Fig. 1) [2]. The bradycardia resolves with removal of the scope from the third ventricle, removal of irrigant if there is obstruction of outflow, and with release of pressure from the floor. If the bradycardia is not recognized, it will invariably progress to asystole and possible hemodynamic compromise. Handler et al reported such an occurrence, which fortunately had no long-term adverse consequences [12].

Avoidance

There are several theories behind the genesis of this problem. Among them is the possibility that the scope obstructs both foramina of Monro, resulting in high pressure within the third ventricle when irrigant cannot escape. Another is that the irrigation fluid is either too different to CSF in osmolality or too cold, resulting in irritation of the hypothalamus. Finally, it may be a pure traction phenomenon of either the floor or walls of the third ventricle and hence hypothalamic dysfunction (Fig.1). Whatever the theory you subscribe to, it would be prudent to obey the following rules:

1. Always check to see that there is an adequate outflow mechanism for the irrigant. Simply having

Fig. 1. Sharp perforation through an opaque floor with the closed end of a pair of grabbing forceps (Aesculap, Tuttingen, Germany)
one of the working channels open does not guarantee egress of fluid. It is not uncommon for a piece of brain or blood clot to obstruct one of these small working/irrigation channels at any time throughout the procedure.

2. Turn up the volume of the cardiac monitor and keep the noise down in the operating room. If the pulse slows, discontinue whatever you happen to be doing, and if possible, reverse the last action.

3. Use isotonic solution, preferably lactated Ringer's, as your irrigant of choice. The fluid should be warmed to approximately body temperature.

4. When puncturing the floor, be sure to use a sharper technique if the floor is thick and nonattenuated (Fig. 1).

Visual Obscuration

There are several causes for a less than optimal view. Of course, the system should be checked before the dura is opened to ensure all components of the video chain are operational. The view can be hindered by fogging of the lenses at any junction, by damaged hardware, and by incorrect assembly of all the different components. The most common cause, however, is intraventricular hemorrhage (Fig. 2). This can occur at any time during the procedure, but usually happens when the ependyma is breached as the scope enters the ventricle for the first time. The bleeding can be minor or quite profuse. It is rarely arterial except when small vessels are torn as the stoma is created. Excessively wide excursions of the scope will increase the chances of bleeding. It is surprising how the spilling of such a small amount of blood may result in such a dramatic effect on visualization. The most important point to remember is not to panic, irrigate generously, and maintain access to the ventricle. Once vision is obscured, try to place the end of the scope in the largest cavity. For example, if hemorrhage occurs when the scope is in the third ventricle, the loss in vision may cause the operator to move the scope only a fraction of a centimeter, which could have drastic consequences. A similar movement in the larger lateral ventricle might not have any adverse result. Once hemorrhage has occurred and irrigation is proving unsuccessful, there are several other techniques that can be employed. The scope itself can be placed against the bleeding vessel to tamponade the flow. Of course, one must first identify the responsible vessel, which may prove difficult given the bloody CSF and visual impairment. The next technique is to try and coagulate the vessel with either monopolar or bipolar endoscopic forceps. In reality this maneuver is very difficult. Endoscopic instruments are not readily steerable and the vessel is often floating around in the CSF, creating a moving target with the copious irrigation. If all else fails, CSF can be removed from the ventricle and replaced with air, thereby allowing the surgeon to use standard coagulating techniques without visual obscuration. It is very important to replace the CSF with air to prevent the ventricles from collapsing, as this can create an even worse set of complications.

Avoidance

Prevention of hemorrhage is clearly the optimal way to manage this dilemma:

1. Tap the ventricle with a smaller brain needle before passing the larger sheath. This will give the sheath easier access and, hopefully, less traction on the ventricular walls.

2. Maintain your trajectory. Try not to move the scope from side to side. A small degree of movement may tear the ependymal vessels.

3. When using a rigid scope, make sure the edges are blunt and rounded. Sharp edges tend to damage vessels (Fig. 3).

4. When using a flexible scope, check that the scope is in the neutral position before removing it.

5. If you are using a technique that requires you to remove and replace scopes into the ventricle it would be wise to use a peel-away sheath in order to maintain a tract through the brain (Fig. 4).
anything larger in diameter than a brain needle. The thickness of either of these implements is such that if you are off target by only a few millimeters, the consequences can be devastating (Fig. 5). Use a standard brain needle, taking note of the depth at which the ventricle is entered, so that the scope or a sheath can be passed down the same tract for precisely the same distance and not a centimeter more.

3. If you inadvertently enter the contralateral ventricle, it is better to abandon that trajectory, remove the scope, and start again. Similarly, if you find the trajectory is taking you to the posterior third ventricle, it is better to discontinue that attempt, remove the scope, make another burr hole more posteriorly, and start again.

4. It is not uncommon for the foramen of Monro to remain relatively small despite quite dramatic ventricular enlargement. Consequently, the scope may be too wide to pass through the foramen. This has been called scope-to-foramen disproportion [27]. Techniques available to circumvent this problem include choosing a smaller-diameter scope or trying to enlarge the foramen with gentle hydrodissection. A less optimal way of avoiding damage is to remove the outer sheaf of the scope and to pass the scope alone into the third ventricle. This would necessitate creating the stoma with the scope itself and without irrigation. Once the scope is within the third ventricle it is important not to wield the scope in wide arcs.

Damage to the Fornices

This is probably the most common complication of ETV [23, 30]. Thankfully, the clinical consequences are minimal or negligible. It usually occurs with the leading face of the endoscope when it is passed from the lateral ventricle into the third. It may also occur when the scope is manipulated within the third ventricle or, rarely, when the scope is removed from the third ventricle. It has been implicated when patients awake with memory disturbance, although it is difficult to imagine bilateral fornixal damage with any of these maneuvers. Bilateral damage is more likely to occur with the initial ventriculostomy, especially when the neurosurgeon uses either the scope itself to tap the lateral ventricle or a peel-away sheath. Another error that may cause bilateral damage is when the scope is placed unknowingly into the contralateral ventricle and the surgeon attempts to pass the scope into the third ventricle.

Avoidance

Damage to the fornix can be avoided by following some simple rules:
1. Optimal burr hole placement (see Chap. 25).
2. Never tap the ventricle with the scope itself or

Fig. 3. This particular scope has sharp edges and is capable of damaging neurovascular structures

Fig. 4. Peel-away sheath used to maintain the tract through the cerebrum

Fig. 5. This hemorrhagic tract was a result of a misguided attempt to access the lateral ventricle with the endoscope itself.
5. If you are using a flexible scope, it must be in the neutral position before backing out of the third ventricle. Faulty scopes that are poorly cleaned often do not return to the neutral position. To avoid this mistake, take note of the trajectory when the scope first enters the third ventricle and before removing the scope ensure that you have returned to the same trajectory.

**Hypothalamic Damage**

This is the most common complication of ETV with clinical consequences [23, 27]. It usually occurs at the time the stoma is created and can result in subclinical or clinically devastating complications. Those complications that have been documented in the literature include permanent or transient diabetes insipidus, amenorrhea, loss of thirst [27], death [19], hyperphagia, varying degrees of drowsiness, hyperkalemia [2], hypotension [31], and decreased insulin-like growth factor 1 [29]. The hypothalamus is particularly susceptible due to its location in the walls of the third ventricle. Indeed, without ventriculomegaly, the floor of the third ventricle is a narrow median raphe where the walls almost meet in the midline. With hydrocephalus, the walls and the raphe attenuate. In reality, the junction between the thinned-out raphe and the attenuated hypothalamus, which may still be functional, is imperceptible. Clearly, any trauma to the floor may result in trauma to the hypothalamus. Thankfully, most hypothalamic complications will be transient. Of those reported in 1995 by the author [27], all have resolved. The one case of amenorrhea that was reported in the original article resolved after 2 years and the case of loss of thirst after 12 months. All cases of diabetes insipidus improved after 2-14 days.

**Avoidance**

1. In cases of acute hydrocephalus, where the floor has not had the opportunity to become transparently thin, ascertaining the safest area to place the stoma can be difficult. Penetrating the floor too anteriorly will likely damage the hypothalamus, while penetrating it too posteriorly may damage the basilar artery. In these circumstances, aggressive irrigation of the floor may sometimes reveal the thinnest area. Alternatively, if one draws an imaginary line between the infundibular recess and the mamillary bodies, making the ventriculostomy approximately between the anterior and middle thirds should diminish the likelihood of neurovascular damage (Fig. 6).

**Fig. 6.** Endoscopic view of the floor of the third ventricle showing the ideal location for creation of the stoma.

2. Blunt techniques to penetrate the floor are less often associated with damage to the basilar artery and its branches. However, when the floor is tough, blunt penetration may require excessive force and subsequent traction on the hypothalamus. A sharper technique may be more appropriate in this setting. The author would recommend the closed end of a pair of grabbing forceps followed by balloon dilatation (Fig. 1).

3. Make the stoma exactly in the midline. A burr hole placed too laterally will result in the scope aiming to the contralateral side of the third ventricle.

**Vascular Damage**

Damage to the basilar artery or its branches is the most life-threatening complication when performing ETV. Certainly, the thought of this complication at the moment of penetration causes more anxiety than any other part of the operation. MRI studies have shown us that the location of the basilar artery bifurcation is quite variable. It is mostly just anterior to the mamillary bodies but can be in juxtaposition to the dorsum sellae or somewhere in between (Fig. 7). However, the perforators are consistently posterior to the bifurcation, on their way to supply the brainstem, and consequently any attempt to perforate the floor must be at least anterior to the bifurcation. When the floor is transparent, the safest area can be readily visualized. When the floor is opaque, puncturing the floor is a blind maneuver. Indeed, in reality all techniques used to penetrate the floor are blind maneuvers as the basilar artery cannot be seen until the floor is breached. More common than damage to the bifurcation itself is damage to the perforators (Fig. 8) [23, 25]. These can be injured when the floor is breached with the penetrating instrument but are also at risk when the initial stoma is enlarged. For example, if one uses the blunt end of a
pair of closed forceps and opens the forceps before retracting them into the third ventricle, devastating hemorrhage may result if a small branch of the basilar artery is caught and avulsed from its parent vessel. Similarly, passing a balloon catheter through the floor, expanding it, and pulling it back through the stoma before deflating it may cause avulsion of a perforating vessel. Different techniques have been proposed in an attempt to avoid these complications [6, 18, 24, 28, 33]. An instrument designed to elevate the floor before perforation is theoretically appealing, but the same movement to elevate the floor could also elevate an underlying vessel. The technique recommended by the author uses the endoscope itself to create the initial hole. The face of an endoscope, 4 mm in diameter, is far too large to penetrate the basilar bifurcation or a perforating vessel. Furthermore, if one uses a 30-degree scope, the face has a leading edge which, when inserted with the leading edge anterior, will naturally push the basilar complex posteriorly, thereby not placing the perforating vessels under any tension. The obvious disadvantage of this technique is the force required to penetrate a thick floor. This added force may stretch the walls of the third ventricle and potentially cause more hypothalamic injury.

Judicious management of hemorrhage from the basilar complex may limit the adverse neurological sequelae of such a disastrous complication [1]. Maintaining access to the ventricle is paramount. Although the endoscope can be removed when visualization is obscured, the sheath should remain within the ventricle so that irrigation can continue until the bleeding stops. This may take up to 45 min. Any attempt to hasten the hemostatic process is usually unsuccessful. Once the bleeding has stopped, the sheath can be removed, an external ventricular drain left within the lateral ventricle, and the wound closed. The patient is then taken to the intensive care unit where the ICP can be monitored and CSF drained if necessary. An angiogram should be arranged when the patient becomes neurologically stable, and if a traumatic aneurysm is found it should be treated appropriately (Fig. 9) [14].

Avoidance

The author has performed over 350 third ventriculostomies using the same technique and has been
fortunate enough to have avoided any vascular complications. The following statements are guidelines based on discussion with colleagues who have had the misfortune to encounter neurovascular injury and who were kind and honest enough to share their experiences. Some of these thoughts have been documented in the literature [1, 16, 23, 25].

1. Choose your endoscope wisely. There are some endoscopic sheaths that have extremely sharp tips that could sever an artery if pushed against it firmly (see Fig. 3). The walls of the sheath need to be smooth.

2. Choose your perforating instrument wisely. Similarly, if you are using a technique that utilizes a smaller instrument passed down a working channel to make the initial hole, the tip of the instrument needs to be blunt. Examples of instruments that have perforated the arterial wall are a pair of grabbing forceps (closed), a 1-mm fiberoptic flexible scope, a Fogarty catheter with stylet, a laser fiber, and a monopolar coagulator.

3. If the floor is opaque and you are relatively inexperienced, it may be wise to abandon the procedure. If you decide to go ahead, then make the hole as anterior as possible, but posterior to the infundibular recess.

4. If you use the scope itself to breach the floor, it is better to use a 30-degree scope with the sloping face looking posteriorly. If the face is directly over the bifurcation, the advancing scope will push the basilar complex posteriorly, avoiding avulsion of the perforators.

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**Cranial Neuropathies**

Damage to cranial nerves is a rare complication that can mostly be avoided by obeying a few simple rules. The cranial nerves most affected are the ocu- lomotor [23] and the abducens. Any damage usually occurs when the floor is bulging downwards, placing the nerves on the stretch; when the floor is perforated, further stretching of the floor causes injury to an already compromised nerve. Diverging from the midline will also put the third cranial nerve at higher risk.

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**Avoidance**

1. Keep to the midline. To achieve this, ensure the burr hole is not too lateral, and make an impres-
General Complications

Seizures

Seizures can occur after any procedure that requires a cortical incision. The incidence may be higher where bone dust is allowed to pollute the cortex. It is important to limit the size of the cortical incision and limit the amount of bone dust once the dura is opened. Patients are not routinely placed on anticonvulsants.

Infection

Any procedure that requires copious ventricular irrigation raises the risk of ventriculitis/meningitis. The author regularly uses prophylactic antibiotics for ETV. The simple act of irrigating the working channels before placing the scope within the ventricle may reduce the incidence of infection. Disposable fiberoptic scopes may further reduce the risk of infection, although this has not been substantiated in the literature. Patients with meningitis following ETV usually present with fever, headache, vomiting, and signs of intracranial hypertension within 2-7 days. The devastating sequel to the meningitis is probable shunt dependence.

Intracerebral Hemorrhage

The true incidence of this complication is probably higher than that documented. The size of the scope is such that hemorrhage is more likely to occur with this passing through the brain than after passage of a smaller-gauge brain needle. Fortunately, the cortical tract is in a relatively noneloquent area and most hemorrhages are asymptomatic. The problem is compounded with collapse of the ventricles after release of CSF.

Avoidance

1. The amount of CSF released with the initial ventricular tap should be limited.
2. The ventricle should be refilled with lactated Ringer’s solution at the completion of the operation before the cortical hole is plugged with Gelfoam.
3. The tract can be inspected when withdrawing the scope from the ventricle. Any obvious sites of hemorrhage can be stopped with either coagulation or simple tamponade with the scope itself.
4. Never use the scope to find the ventricle. It should only be introduced when the ventricle has been found with either a stereotactic probe, a ventricular catheter, or a brain needle. Even then, the scope should be marked at a point 5-6 cm from the tip so that it is never blindly introduced further than the depth of the ventricle.

CSF Leak

This is one of the more common and potentially damaging complications. The explanation is simple. Noncommunicating hydrocephalus can give rise to secondary communicating hydrocephalus and, conversely, obstructive hydrocephalus may occur simultaneously with communicating hydrocephalus. Thus, a patient who has an ETV for apparent noncommunicating hydrocephalus may have associated communicating hydrocephalus and will therefore fail to absorb the additional fluid load, at least not in the immediate short term. This theory accounts for why some patients need several days or even weeks to improve clinically and radiologically after ETV. CSF within the ventricular and subarachnoid spaces is under pressure in an attempt to create a gradient resulting in bulk flow across the villi into the sagittal sinus. It is not uncommon for patients after ETV to have significant subgaleal CSF collections over the burr hole. This will progress to CSF leak if the wound breaks down or if the absorption from the arachnoid villi continues to be inadequate. External ventricular drainage or lumbar tappings (see Chap. 25) have been advocated by some to address this immediate fluid imbalance. However, draining CSF externally discourages the re-establishment of normal CSF flow, possibly increasing the chance of the stoma closing, which in turn may increase the number of failures. This phenomenon has been well documented by those neurosurgeons who have monitored the CSF pressure in the postoperative period and who have resisted draining off any fluid. It can persist for many days.

Avoidance

1. The author uses Gelfoam (Upjohn, Kalamazoo) to plug the cortical tract. This may help prevent subdural hygromata and CSF leak. The use of bone wax to plug the burr hole appears attractive but probably reduces the healing capacity in the long term and may increase the risk of infection.
2. Water-tight wound closure is imperative.
3. Intermittent lumbar punctures in the immediate postoperative period may reduce the incidence of CSF leak but may also increase the failure rate.
4. The patient should be kept as upright as possible in the postoperative period. This will serve to reduce the CSF pressure on the wound and decrease the sagittal sinus pressure, thereby augmenting the CSF-to-sinus gradient.

**Postoperative Neurological Deficit**

The two most common causes of neurological deficit after ETV are damage when tapping the ventricle and persevering with the procedure despite poor visualization. The ventricle should never be tapped with the sheath of the scope or a peel-away sheath. Both these instruments are significantly thicker than a brain needle and may cause substantial damage if passed into structures other than the ventricle. The best technique for gaining access to the ventricle is to make the initial trajectory with a thin needle; once access has been achieved, the scope can be passed along the tract under direct visualization. Once the scope is in the ventricle, direct visualization makes the possibility of damaging surrounding neural structures extremely unlikely. However, if one persists in spite of poor visualization, neural injury can happen with very little effort. Nonspecific neurological sequelae after ETV such as confusion, drowsiness, and irritability can be secondary to many events. Some potential steps in the operation where general neurological injury may occur are: irrigating within the ventricles with either cold or nonisotonic solution, stretching of the hypothalamus with third ventricular manipulation, rapid changes in intracranial pressure with irrigation and subsequent brain shifts, subarachnoid hemorrhage either with the cortical incision or creation of the stoma, and vasospasm secondary to manipulation of the vessels within the interpeduncular cistern.

**Avoidance**

1. Never tap the ventricle with the scope or the scope sheath.
2. Always check the scope or the sheath for centimeter markings so that it is never passed more than 5 cm below the cortical surface.
3. Once good visualization is obscured with hemorrhage, either clear it with irrigation or, failing this, abandon the procedure. Do not persevere with ventricular navigation by feel. There is virtually no tactile feedback in endoscopy.

**Subdural Hematoma**

Subdural hematoma is a not uncommon complication of any intracranial procedure that causes a significant reduction to intracranial volume. Removing a large tumor, for example, can cause the brain to collapse, with subsequent unilateral, contralateral, or bilateral acute or chronic subdural hematoma. Similarly, permitting excessive loss of CSF during the operation may cause collapse of the cortical mantle and formation of acute subdural hematoma. Almost invariably the collections are small and asymptomatic (Fig. 10), but occasionally they can be massive with serious clinical consequences [17]. Clearly, the solution is to try to keep the ventricles from collapsing.

![Fig. 10. Asymptomatic subdural hematoma seen 3 months after an ETV. This resolved spontaneously.](Image)
Avoidance

1. After tapping the ventricle with the thin brain needle, ensure the cortical incision is big enough to admit the endoscope without causing displacement of the underlying brain.
2. Do not allow CSF to escape in large quantities.
3. Refill the ventricles when CSF does escape.
4. Coagulate all cortical bleeding vessels before closing.

Summary

Surgical Training

The ideal training platform is where the resident learns from the master. This is happening more and more, but there are still a significant number of neurosurgeons who have never been exposed to neuroendoscopy. Unfortunately, these neurosurgeons who did not have the luxury of training in a unit that offered specialized training in endoscopy admit that ETV should be a part of their surgical armamentarium. These practitioners have two options. They can either take time off to visit and learn from a center that does practice endoscopy, or they can enroll in a course. The course should offer teaching in the anatomy of the ventricular system, patient selection, surgical technique, complication avoidance, and postoperative management. It should have a hands-on practical component using cadavers that have been specifically prepared for intraventricular surgery. The course faculty should ideally have extensive experience in endoscopy, and the course should have accreditation for continuing education. Subsequently, the novice neurosurgeon would be well served to have an assistant for his first case who has had some experience with this procedure.

Patient Selection

All patients with noncommunicating hydrocephalus are candidates for ETV. However, to reduce the rate of complications, the ideal candidate would have large ventricles, a third ventricle wider than the diameter of the scope/sheath, an attenuated third ventricular floor, a capacious interpeduncular cistern, and no aberrant anatomy [21]. Of course, with experience, the selection criteria can be liberalized without jeopardizing the patients. The best way to assess these anatomical prerequisites is with MRI (Fig. 11). The etiology of the hydrocephalus may also be a significant prognosticator [3], e.g., a patient with secondary aqueduct stenosis should do better than one with postmeningitic hydrocephalus.

Postoperative Management

The patient is recovered in the ward and encouraged to mobilize as soon as possible. The author would discourage the use of external ventricular drainage for any period of time or intermittent lumbar punctures. There is no evidence to suggest whether this is a wise move or not. Parents, patients, and caregivers should be warned that all symptoms may not resolve rapidly. Indeed, if they are improved but not absolutely normal, time should be given for possible complete resolution. Serial CT scans may be helpful if they show change, but it should be noted that persistence of ventriculomegaly is usual. Finally, this operation is not a cure. Patients need regular surveillance, like those with shunts, as long-term failures have been known to occur [11, 15].

References