Complications of Endoscopic Third Ventriculostomy

Michael DeCuypere and Charles Teo

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Abstract

Endoscopic third ventriculostomy is considered by many as one of the greatest breakthroughs in the management of hydrocephalus and is the most commonly performed neuroendoscopic procedure. Neurosurgeons have pushed the boundaries of this procedure beyond the classic indication of aqueductal stenosis to include hydrocephalus

M. DeCuypere
Department of Neurosurgery, University of Tennessee Health Science Center, Memphis, TN, USA
e-mail: mdecuype@uthsc.edu

C. Teo (✉)
Centre for Minimally Invasive Neurosurgery, Prince of Wales Hospital, Randwick, NSW, Australia
e-mail: enquiry@neuroendoscopy.info

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of many other etiologies. Even as this technique becomes more conventional within neurosurgery, there is a distinct learning curve associated with the procedure, and many of the complications can be quite serious in nature. These can occur intraoperatively (bradycardia, hemorrhage, neural structure injury) and postoperatively (hygroma, hematoma, CSF leak, infection, seizures). Clearly, a thorough understanding of these potential pitfalls is obligatory for the skilled surgeon. This chapter will review the etiology and relative frequency of complications associated with endoscopic third ventriculostomy. Emphasis is placed on complication avoidance, and recommendations are given to encourage prevention in every phase of the procedure.

Keywords
Endoscopic third ventriculostomy · Complications · Cranial endoscopy · Intracranial hemorrhage · CNS infection · CSF leak

Introduction

Endoscopic third ventriculostomy (ETV) is the most commonly performed neuroendoscopic procedure and is typically advocated for the management of obstructive hydrocephalus at the cerebral aqueduct (aqueductal stenosis, posterior fossa tumors, etc.) (Ruggiero et al. 2004; Grunert et al. 2003). However, there is mounting support for the effectiveness of ETV in the management of hydrocephalus of other etiologies. These include posthemorrhagic, post-infectious, congenital communicating, myelomeningocele-related, and Chiari malformation-related, among others (Hailong et al. 2008; Sacko et al. 2010; Kulkarni et al. 2016; Teo and Jones 1996). As ETV is clearly preferable to VP shunt placement on a conceptual level, many neurosurgeons continue to push the boundaries of its use.

The vast majority of published studies on ETV focus on success rate and factors that lead to long-term efficacy. However, there is a distinct learning curve associated with the procedure, and many of the complications can be quite serious in nature (Bouras and Sgouros 2011; Baykan et al. 2005; Dusick et al. 2008; Ersahin and Arslan 2008; Hader et al. 2002; Navarro et al. 2006; Schroeder et al. 2002). With the rising popularity and ubiquity of ETV, a thorough understanding of the procedural complications is mandatory. The following chapter will review the complications associated with ETV, with an emphasis on avoidance.

Intraoperative Complications of ETV

Bradycardia and Asystole

This intraoperative complication has been recognized for many years (El-Dawlatly et al. 2000; Handler et al. 1994). It has been identified as a not uncommon, transient 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: when the scope is introduced, when irrigation is used, or when pressure is placed on the floor of the third ventricle (Fig. 1) (Anandh et al. 2002). The bradycardia is usually short-lived and

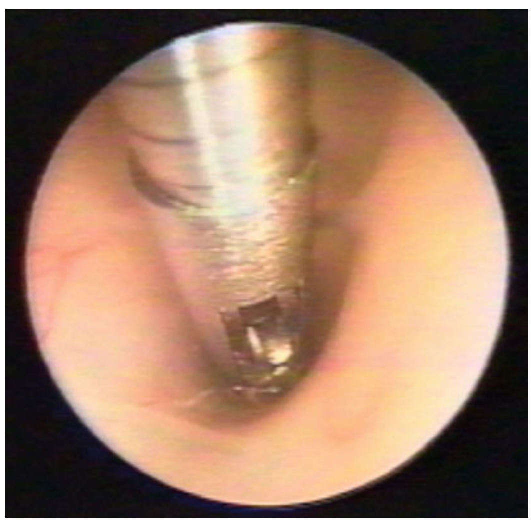

Fig. 1 Sharp perforation through an opaque floor with the closed end of a pair of grabbing forceps (Aesculap, Tutlingen, Germany)

resolves with the removal of the scope from the third ventricle, with removal of irrigant if there is obstruction of outflow, and with release of pressure from the floor. If the bradycardia is not recognized, however, it will invariably progress to asystole and possible hemodynamic compromise. These incidents may sometimes be incorrectly attributed to general anesthesia, and thus the surgeon should remain vigilant. These events, typically minor and likely underreported in the literature, represent approximately 0.1% of incidents (Bouras and Sgouros 2011).

Avoidance

There are several theories for the etiology of this phenomenon. Among them is the possibility that the scope obstructs both foramina of Monro, resulting in high pressure within the third ventricle when irrigation cannot escape. Another is the difference of the osmolality or temperature of the irrigation fluid from that of CSF, resulting in irritation of the hypothalamus. Finally, it may be a pure traction phenomenon of either the floor or walls of the third ventricle, which leads to hypothalamic dysfunction (Fig. 1). Whatever 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 irrigation fluid. Simply having one of the working channels open does not guarantee egress of fluid. It is not uncommon for brain tissue or blood clot to obstruct one of these small working 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 solution, 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 non-attenuated.

Visual Obstruction

There are several causes for suboptimal view. Of course, the system should be checked before 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 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. 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

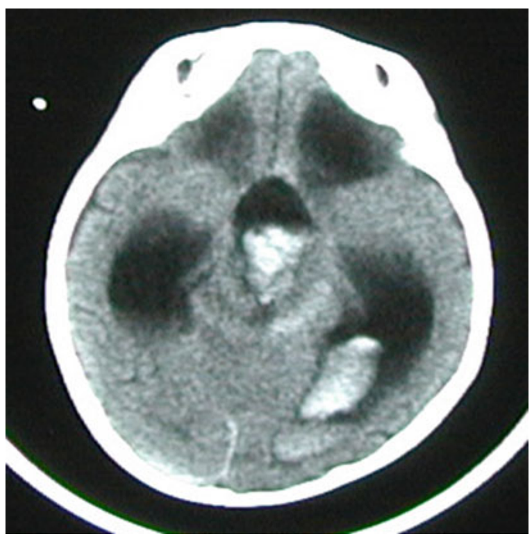

Fig. 2 Postoperative CT of a child who had an ETV complicated by intraoperative hemorrhage that occurred at the time of the ventriculocisternostomy

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 maneuverable, 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 lead to different, and typically more serious, complications.

Fig. 3 19 French peel-away endoscope sheath (left) and 8 French brain cannula (right). The brain cannula has a 2.5 mm outer diameter

Avoidance

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

1. Tap the ventricle with a smaller brain cannula (brain needle; Scott Cannula [Codman, Raynham, MA, USA]) before passing the larger sheath. This will give the sheath easier access and, hopefully, less traction on the ventricular walls (Fig. 3).
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. Sharp edges tend to damage vessels (Fig. 4). When using a rigid scope, make sure the edges are blunt and rounded. Older scopes may have sharp edges, unlike more modern scopes. Similarly, endoscope trocars (with working channels) tend to have rounded edges.
4. When using a flexible scope, check that the scope is in the neutral position before removing it.
5. If you are utilizing 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. 3).

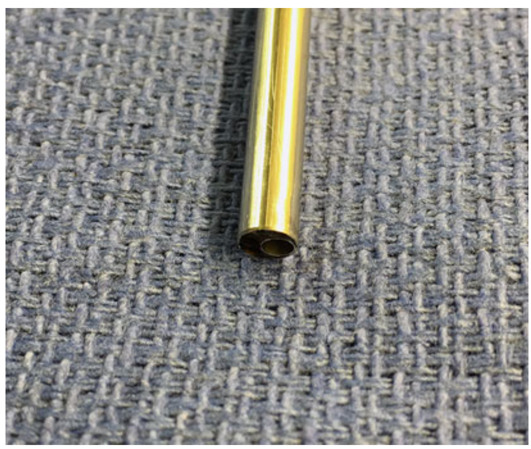

Fig. 4 This particular endoscope has sharp edges and is capable of damaging neurovascular structures

Neural Injury

The second most common intraoperative complication associated with ETV, after bleeding/hemorrhage, is damage of neural structures. Damage to periventricular or intraventricular structures has been reported in 0.24% of 2985 ETVs (Bouras and Sgouros 2011). These structures include the thalamus (0.12%), fornices (0.04%), hypothalamus (0.04%), and midbrain (0.04%). However, the degree of trauma that constitutes injury or damage remains open to interpretation, and these instances are very likely underreported. This is underscored by the higher rates of reported neurological and hormonal morbidity. This may imply that the majority of these incidents occur without being appreciated. However, a recent large series of 336 pediatric ETVs in North American centers reported small, clinically insignificant contusion of the fornix occurred in 12.8% of cases (Kulkarni et al. 2016). This was attributed to higher vigilance of complication reporting.

Damage to the Fornices

Although trauma to the ipsilateral fornix is seemingly a common complication of ETV, the clinical consequences are usually minimal or negligible (Schroeder et al. 2002; Teo et al. 1996). It usually occurs when the leading face of the endoscope 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 forniceal 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 is paramount. We typically use the following surface landmarks: 1 cm anterior to the coronal suture and 3 cm lateral to midline.
2. Never access the ventricle with the endoscope itself or anything larger in diameter than a brain cannula. 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. 3). Use a standard brain cannula, 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 (scope-to-foramen disproportion). Techniques available to circumvent this problem include choosing a smaller-diameter scope or trying to enlarge the foramen with gentle irrigation and hydrodissection. A less optimal way of avoiding damage is to remove the endoscope trocar (if used) 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.
5. If you are using a flexible endoscope, 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 intraoperative neural injury caused during ETV with postoperative clinical consequences (Schroeder et al. 2002; Teo et al. 1996). It usually occurs at the time the stoma is created and can result in subclinical or clinically devastating complications. The complications that have been documented in the literature include permanent or transient diabetes insipidus, amenorrhea, loss of thirst, hyperphagia, varying degrees of drowsiness, hyperkalemia, hyponatremia, decreased insulin-like growth factor, and even death (Anandh et al. 2002; Vaicys and Fried 2000; Dusick et al. 2008; Hader et al. 2008; Hailong et al. 2008; Kim et al. 2000). 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 tend to be transient. Permanent rates of diabetes insipidus (0.64%), weight gain (0.27%), and precocious puberty (0.04%) are low in the reported literature (Bouras and Sgouros 2011).

Avoidance

1. In cases of acute hydrocephalus, where the floor has not had the opportunity to become sufficiently 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.

Fig. 5 Although this MRI shows clear triventricular ventriculomegaly secondary to aqueduct stenosis, the floor of the third ventricle is extraordinarily thick

   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.
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 (Fig. 5). We advocate a sharper technique in this setting and 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.

Cranial Neuropathies

The cranial nerves most injured during ETV are the oculomotor and abducens (Schroeder et al. 2002). Gaze palsy has been reported to occur in 0.6% of procedures (Bouras and Sgouros 2011). Damage usually occurs when the floor is bulging downward, placing the nerves on the stretch. Injury may also occur when the floor is perforated, whereby 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.

Avoidance

Damage to cranial nerves is a rare complication that can mostly be avoided by obeying a few simple rules:

1. Keep to the midline. To achieve this, ensure the burr hole is not placed too far lateral, and make an impression on the floor before perforating it so that you can pull the scope back slightly to visualize exactly where the stoma will be placed. Do not push the scope or perforating instrument too far below the floor, and do not push too vigorously on an already stretched floor.
2. Be aware of aberrant anatomy. The third cranial nerves can follow a course close to the midline on their way to the cavernous sinus. It would be wise to review thin slice T2 weighted MRI sequences during preoperative planning.

Vascular Damage

Hemorrhage is the most common intraoperative complication of ETV, and, as expected, its reporting is variable due to threshold differences for the definition (Egger et al. 2010, Hopf et al. 1999, Kadrian et al. 2005, Scarrow et al. 2000, Schroeder et al. 2002, van Beijnum et al. 2008). In the review of Bouras and Sgouros, the overall rate of hemorrhagic incidents reported was 3.7% (Bouras and Sgouros 2011). In 0.6% of cases, the hemorrhage was considered severe. In contrast, Kulkarni et al. reported a hemorrhage rate of moderate or severe of 6% in pediatric cases (Kulkarni et al. 2016). Clearly, there is a difference of definition in this instance, and these numbers cannot accurately be compared.

Damage to the basilar artery, or its branches, is the most life-threatening complication when performing ETV. It was reported in 0.21% of procedures reviewed by Bouras and Sgouros (2011). Kulkarni et al. reported a similar rate of major arterial injury at 0.3% (Kulkarni et al. 2016). 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 can be quite variable. It is most commonly just anterior to the mamillary bodies but can be in juxtaposition to the dorsum sella or somewhere in between. 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, however, puncturing the floor is a blind maneuver. 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. 6) (Schroeder et al. 1999, 2002). 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 closed forceps and opens the forceps before retracting them into the third ventricle, devastating hemorrhage may result if a

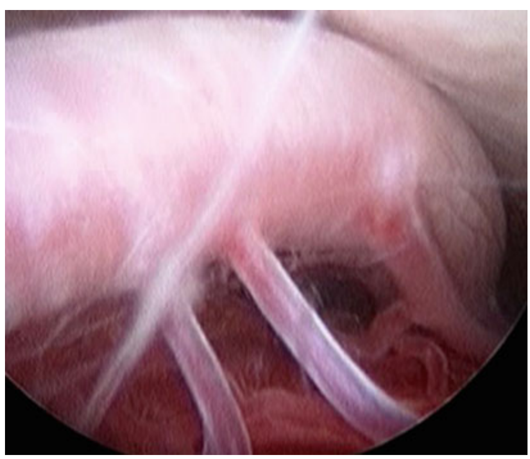

Fig. 6 View of the perforators coming off the back of the basilar complex. If they are damaged, severe neurological sequela may result

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. Several techniques have been proposed in an attempt to avoid these complications (Decq et al. 2000; Paladino et al. 2000; Schroeder et al. 2001; Wellons et al. 1999). 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. We recommend using the endoscope itself to create the initial perforation. The face of an endoscope, 4 mm in diameter, is far too large to penetrate the basilar bifurcation or a perforating vessel directly. 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 (Fig. 7), thereby not placing the perforating vessels under any tension. The obvious disadvantage of this technique is the added force required to penetrate a thick floor, which may stretch the walls of the third ventricle and potentially cause hypothalamic injury.

Judicious management of hemorrhage from the basilar complex may limit the adverse neurological sequela of such a disastrous complication (Abtin et al. 1998). 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. 8) (Horowitz et al. 2001; Mclaughlin et al. 1997).

Avoidance

The following consensus statements are guidelines based on discussion with neuroendoscopic colleagues who have had the misfortune to encounter neurovascular injury. Some of these thoughts have been documented in the literature (Abtin et al. 1998; Mclaughlin et al. 1997; Schroeder et al. 1999).

1. Choose your endoscope wisely. There are some endoscopic sheaths that have extremely

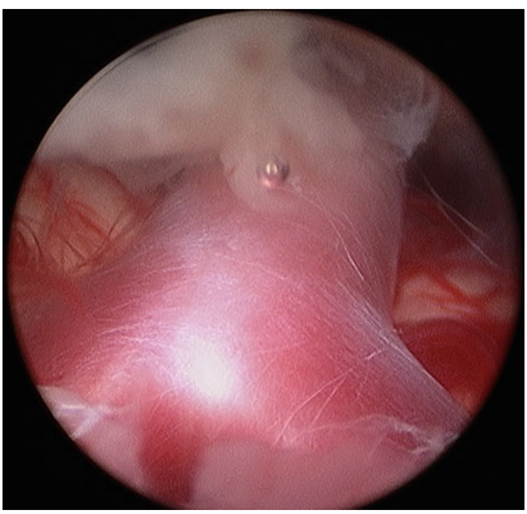

Fig. 7 View of the basilar artery complex (looking posteriorly) as the stoma is created with the 30° endoscope

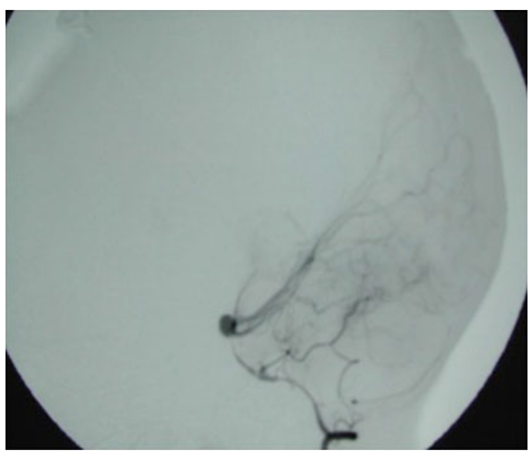

Fig. 8 Angiogram of a child taken 7 days after a complicated ETV. The surgeon experienced torrential hemorrhage after creating the ventriculocisternostomy and implicated the sharp edge of the scope as the causative factor

sharp tips that could sever an artery if pushed against it firmly (Fig. 4). The walls of the sheath need to be smooth.

2. Choose your perforating instrument wisely. Similarly, if you are using a technique that utilizes smaller instruments passed down a working channel to make the initial hole, the tip of the instrument should be blunt. Examples of instruments that have perforated the arterial wall are a pair of grabbing forceps (closed), a 1-mm fiber-optic 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 proceed, make the perforation 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 (Fig. 7). If the face is directly over the bifurcation, the advancing scope will push the basilar complex posteriorly, avoiding avulsion of the perforators.

Postoperative Complications of ETV

Subdural Hygroma

While more common after VP shunt placement, subdural CSF collections after ETV is another well-documented complication that probably occurs more frequently than the reported rate of 0.27% (Bouras and Sgouros 2011; Kurschel et al. 2007; Freudenstein et al. 2002). The presumed pathophysiology is that CSF forces its way through the frontal endoscope tract and into the subdural space (Fig. 9). It does so because the newly created “normal” pathways and the absorptive mechanisms of CSF need time to mature. Naturally, CSF tries to escape through the pathway of least resistance. Indeed, some of these patients have eventually required extracranial CSF diversion, implying that the absorptive mechanisms were always faulty (Freudenstein et al. 2002; Kurschel et al. 2007).

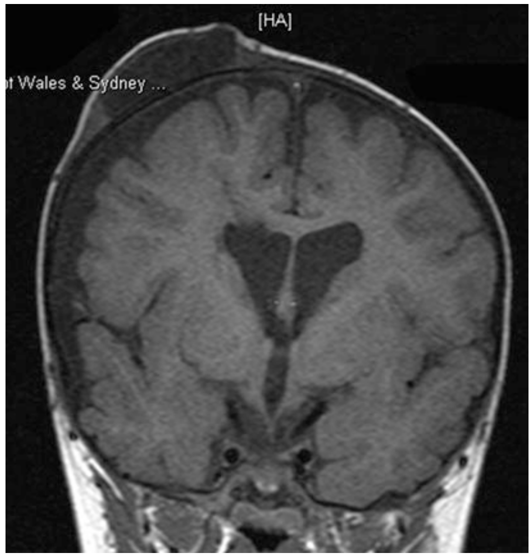

Fig. 9 Coronal MRI demonstrating subdural hydroma with pseudomeningocele several days after ETV

Avoidance

It is difficult to identify the true pathogenesis of this condition, but as the authors have not had this complication in the last 350 cases, it may be prudent to follow the same protocol:

1. The ventricle should be expanded before removing the sheath from the lateral ventricle.
2. The cortical endoscope tract should be plugged with Gelfoam (Pfizer, New York, NY, USA).
3. Lumbar and ventricular drainage should be avoided in the postoperative period.

Subdural Hematoma

Subdural hematoma is a not uncommon complication of any intracranial procedure that causes a significant reduction to intracranial volume. Bouras and Sgouros identified a rate of occurrence of 0.3%, on par with the rate of intraventricular hemorrhage (Bouras and Sgouros 2011). Removing a large tumor, for example, can cause the brain to collapse, with subsequent unilateral, contralateral, or bilateral acute or chronic subdural hematomas (Ruggiero et al. 2004). Similarly, permitting excessive loss of CSF during the operation may cause collapse of the cortical mantle

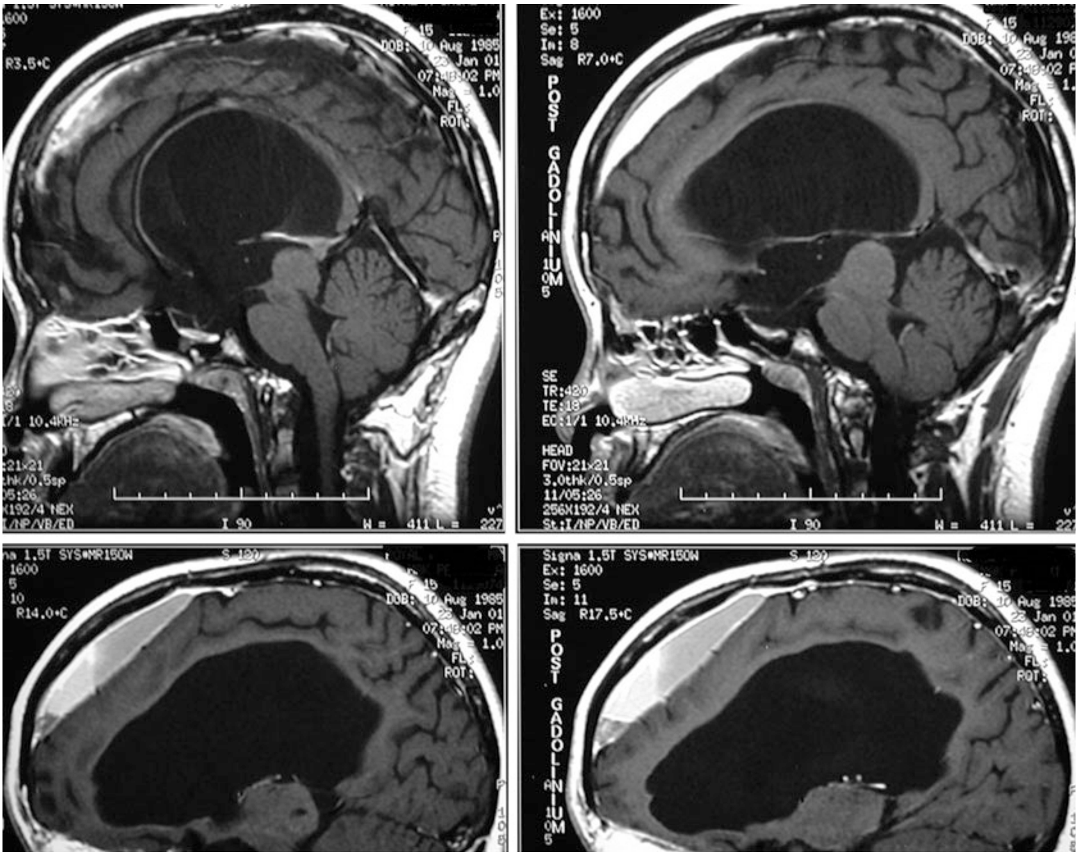

Fig. 10 Asymptomatic subdural hematoma seen 3 months after an ETV. This resolved spontaneously

and formation of acute subdural hematoma (Ogiwara et al. 2010; Navarro et al. 2006). Almost invariably the collections are small and asymptomatic (Fig. 10), but occasionally they can be massive with serious clinical consequences (Mohanty et al. 1997).

Avoidance

Clearly, the solutions are meticulous cortical hemostasis and to try to keep the ventricles from collapsing:

1. After tapping the ventricle with the thin brain cannula, 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. Refill the ventricles when CSF does escape.
3. Coagulate all cortical bleeding vessels before closing.

Intracerebral Hemorrhage

The true incidence of this complication is probably higher than that documented at 0.15% (Bouras and Sgouros 2011). 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 non-eloquent area, and most hemorrhages are asymptomatic (Fig. 11). 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.

Fig. 11 ETV tract hemorrhage noted on postoperative imaging. This was created while using a peel-away sheath to access the ventricle

3. The tract can be directly 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 a stereotactic probe, a ventricular catheter, or a brain cannula. 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. Bouras and Sgouros report an incidence of 1.6%, while Kulkarni et al. reported an incidence of 4.4% after ETV (Bouras and Sgouros 2011; Kulkarni et al. 2016). The explanation for this complication is a relatively simple one. Non-communicating 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 non-communicating 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 (Fig. 9). 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 puncture has 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 closure, which in turn may increase the rate of failure. This phenomenon has been well documented by those neurosurgeons who have monitored CSF pressure in the postoperative period and who have resisted draining off any fluid. It can persist for many days.

Avoidance

1. Use Gelfoam (Pfizer, New York, NY, USA) to plug the cortical tract. This may help prevent subdural hygroma 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. Meticulous, watertight 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.

CNS Infection

Any procedure that requires copious ventricular irrigation raises the risk of ventriculitis/meningitis. Infectious complications have a reported incidence of 1.81% (meningitis 1.6%; ventriculitis 0.21%) (Bouras and Sgouros 2011). Sub-cortical brain abscess has also been reported after ETV (Grand et al. 2016). CSF leak is certainly not necessary for infection to occur, and CSF leak is generally not considered a risk factor for infection by several authors (Ersahin and Arslan 2008, Hader et al. 2008, Navarro et al. 2006, van Beijnum et al. 2008). Disposable fiber-optic 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. However, CNS infection may lead to sepsis (0.8%) and even death (Hader et al. 2008; Schroeder et al. 2002; Grand et al. 2016).

Avoidance

1. We regularly use prophylactic antibiotics for ETV.
2. The simple act of irrigating the working channels before placing the scope into the ventricle may reduce the incidence of infection.

Postoperative Neurological Deficit

Nonspecific neurological sequela 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 non-isotonic 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. Transient akinetic mutism has been postulated to be secondary to thalamic injury (Dusick et al. 2008). Bouras and Sgouros report incidences of decreased consciousness (0.34%), hemiparesis (0.34%), and memory disorders (0.17%), contributing to an overall postoperative neurological deficit rate of 1.44% (Bouras and Sgouros 2011). Kulkarni et al. report a similar postoperative neurological deficit rate of 1.5% (Kulkarni et al. 2016).

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.

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. We do not routinely use prophylactic anticonvulsant medications.

Others

Several other complications have been documented after ETV. The incidence of systemic complications after ETV has been reported as 2.34% (Bouras and Sgouros 2011). The most frequent were systemic infection and deep vein thrombosis. However, other documented complications include pneumonia, pulmonary embolism, urinary retention, renal failure, hypotension, and bradycardia. Thomson et al. reported three cases of hypertrophic calcification within the cerebral matter after ETV (Thomson et al. 2003). They postulated that this complication was iatrogenic from sealing the burr hole with bone dust at the conclusion of the procedure.

Postoperative Management

The patient is typically sent for ward observation, encouraged to mobilize soon, and sit upright as much as possible. We 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 strategy 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 (Hader et al. 2002).

Patient Selection

All patients with non-communicating 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 (Rohde and Gilsbach 2000). Of course, with experience, the selection criteria can be liberalized without jeopardizing patients. The etiology of the hydrocephalus may also be a significant prognosticator, e.g., a patient with secondary aqueductal stenosis should do better than one with post-meningitic hydrocephalus (Kulkarni et al. 2011).

Summary

As mentioned previously, there is a clearly a lack of consensus regarding incidents that are recorded as complications with regard to ETV. In the review of Bouras and Sgouros, the mean overall complication rate was reported as 8.5% (range 0–31.2%). The permanent overall morbidity rate was reported as 2.38%, with more modest variation (0–9.1%). Thankfully, the mortality rate associated with ETV was low and reported as 0.28% (Bouras and Sgouros 2011). It should be mentioned, however, that there have been reports of sudden death events after uneventful ETV. These have occurred at 5 weeks to 7.8 years after ETV (Drake et al. 2006; Hader et al. 2002). In these cases, death was the result of massive hydrocephalus caused by stoma occlusion. It appears that this complication is very rare (0.07% incidence); however, patients and families should always be informed of this possibility, and surgeons should remain vigilant with follow-up.

ETV is now a well-established procedure for the effective management of hydrocephalus. In general, ETV may be regarded as a safe procedure with relatively low rates of morbidity and mortality. Unfortunately, while many retrospective series exist in the literature, prospective data regarding specific intraoperative events and their impact on complications and success is absent and much needed. As with all surgical procedures, avoidance and prevention is the best approach. By adhering to the guidelines presented herein, we hope to make this procedure safer and more effective in the hands of less-experienced neuroendoscopists.

References

Abtin K, Thompson BG, Walker ML (1998) Basilar artery perforation as a complication of endoscopic third ventriculostomy. Pediatr Neurosurg 28:35–41

Anandh B, Madhusudan Reddy KR, Mohanty A, Umamaheswara Rao GS, Chandramouli BA (2002) Intraoperative bradycardia and postoperative hyperkalemia in patients undergoing endoscopic third ventriculostomy. Minim Invasive Neurosurg 45:154–157

Baykan N, Isbir O, Gercek A, Dagcnar A, Ozek MM (2005) Ten years of experience with pediatric neuroendoscopic third ventriculostomy: features and perioperative complications of 210 cases. J Neurosurg Anesthesiol 17:33–37

Bouras T, Sgouros S (2011) Complications of endoscopic third ventriculostomy. J Neurosurg Pediatr 7:643–649

Decq P, Le Guerinel C, Palfi S, Djindjian M, Keravel Y, Nguyen JP (2000) A new device for endoscopic third ventriculostomy. J Neurosurg 93:509–512

Drake J, Chumas P, Kestle J, Pierre-Kahn A, Vinchon M, Brown J, Pollack IF, Arai H (2006) Late rapid deterioration after endoscopic third ventriculostomy: additional cases and review of the literature. J Neurosurg 105:118–126

Dusick JR, Mcarthur DL, Bergsneider M (2008) Success and complication rates of endoscopic third ventriculostomy for adult hydrocephalus: a series of 108 patients. Surg Neurol 69:5–15

Egger D, Balmer B, Altermatt S, Meuli M (2010) Third ventriculostomy in a single pediatric surgical unit. Childs Nerv Syst 26:93–99

El-Dawlatly AA, Murshid WR, Elshimy A, Magboul MA, Samarkandi A, Takrouri MS (2000) The incidence of bradycardia during endoscopic third ventriculostomy. Anesth Analg 91:1142–1144

Ersahin Y, Arslan D (2008) Complications of endoscopic third ventriculostomy. Childs Nerv Syst 24:943–948

Freudenstein D, Wagner A, Ernemann U, Duffner F (2002) Subdural hygroma as a complication of endoscopic neurosurgery – two case reports. Neurol Med Chir (Tokyo) 42:554–559

Grand W, Leonardo J, Chamczuk AJ, Korus AJ (2016) Endoscopic third ventriculostomy in 250 adults with hydrocephalus: patient selection, outcomes, and complications. Neurosurgery 78:109–119

Grunert P, Charalampaki P, Hopf N, Filippi R (2003) The role of third ventriculostomy in the management of obstructive hydrocephalus. Minim Invasive Neurosurg 46:16–21

Hader WJ, Drake J, Cochrane D, Sparrow O, Johnson ES, Kestle J (2002) Death after late failure of third ventriculostomy in children. Report of three cases. J Neurosurg 97:211–215

Hader WJ, Walker RL, Myles ST Hamilton M (2008) Complications of endoscopic third ventriculostomy in previously shunted patients. Neurosurgery 63, ONS168–174; discussion ONS174–175

Hailong F, Guangfu H, Haibin T, Hong P, Yong C, Weidong L, Dongdong Z (2008) Endoscopic third ventriculostomy in the management of communicating hydrocephalus: a preliminary study. J Neurosurg 109:923–930

Handler MH, Abbott R, Lee M (1994) A near-fatal complication of endoscopic third ventriculostomy: case report. Neurosurgery 35:525–527; discussion 527–528

Hopf NJ, Grunert P, Fries G, Resch KD, Perneczky A (1999) Endoscopic third ventriculostomy: outcome analysis of 100 consecutive procedures. Neurosurgery 44:795–804; discussion 804–806

Horowitz M, Albright AL, Jungreis C, Levy EI, Stevenson K (2001) Endovascular management of a basilar artery false aneurysm secondary to endoscopic third ventriculostomy: case report. Neurosurgery 49:1461–1464; discussion 1464–1465

Kadrian D, Van Gelder J, Florida D, Jones R, Vonau M, Teo C, Stening W, Kwok B (2005) Long-term reliability of endoscopic third ventriculostomy. Neurosurgery 56:1271–1278 discussion 1278

Kim SK, Wang KC, Cho BK (2000) Surgical outcome of pediatric hydrocephalus treated by endoscopic III ventriculostomy: prognostic factors and interpretation of postoperative neuroimaging. Childs Nerv Syst 16:161–168 discussion 169

Kulkarni AV, Riva-Cambrin J, Browd SR (2011) Use of the ETV success score to explain the variation in reported endoscopic third ventriculostomy success rates among published case series of childhood hydrocephalus. J Neurosurg Pediatr 7:143–146

Kulkarni AV, Riva-Cambrin J, Holubkov R., Browd SR, Cochrane DD, Drake JM, Limbrick DD, Rozzelle CJ, Simon TD, Tamber MS, Wellons JC 3rd, Whitehead WE, Kestle JR, Hydrocephalus Clinical Research Network (2016) Endoscopic third ventriculostomy in children: prospective, multicenter results from the Hydrocephalus Clinical Research Network. J Neurosurg Pediatr 18(4):423–429

Kurschel S, Ono S, Oi S (2007) Risk reduction of subdural collections following endoscopic third ventriculostomy. Childs Nerv Syst 23:521–526

Mclaughlin MR, Wahlig JB, Kaufmann AM, Albright AL (1997) Traumatic basilar aneurysm after endoscopic third ventriculostomy: case report. Neurosurgery 41:1400–1403 discussion 1403–1404

Mohanty A, Anandh B, Reddy MS, Sastry KV (1997) Contralateral massive acute subdural collection after endoscopic third ventriculostomy – a case report. Minim Invasive Neurosurg 40:59–61

Navarro R, Gil-Parra R, Reitman AJ, Olavarria G, Grant JA, Tomita T (2006) Endoscopic third ventriculostomy in children: early and late complications and their avoidance. Childs Nerv Syst 22:506–513

Ogiwara H, Dipatri AJJR, Alden TD, Bowman RM, Tomita T (2010) Endoscopic third ventriculostomy for obstructive hydrocephalus in children younger than 6 months of age. Childs Nerv Syst 26:343–347

Paladino J, Rotim K, Stimac D, Pirker N, Stimac A (2000) Endoscopic third ventriculostomy with ultrasonic contact microprobe. Minim Invasive Neurosurg 43:132–134

Rohde V, Gilsbach JM (2000) Anomalies and variants of the endoscopic anatomy for third ventriculostomy. Minim Invasive Neurosurg 43:111–117

Ruggiero C, Cinalli G, Spennato P, Aliberti F, Cianciulli E, Trischitta V, Maggi G (2004) Endoscopic third ventriculostomy in the treatment of hydrocephalus in

posterior fossa tumors in children. Childs Nerv Syst 20:828–833
Sacko O, Boetto S, Lauwers-Cances V, Dupuy M, Roux FE (2010) Endoscopic third ventriculostomy: outcome analysis in 368 procedures. J Neurosurg Pediatr 5:68–74
Scarrow AM, Levy EI, Pascucci L, Albright AL (2000) Outcome analysis of endoscopic III ventriculostomy. Childs Nerv Syst 16:442–444 discussion 445
Schroeder HW, Warzok RW, Assaf JA, Gaab MR (1999) Fatal subarachnoid hemorrhage after endoscopic third ventriculostomy. Case report. J Neurosurg 90:153–155
Schroeder HW, Wagner W, Tschiltschke W, Gaab MR (2001) Frameless neuronavigation in intracranial endoscopic neurosurgery. J Neurosurg 94:72–79
Schroeder HW, Niendorf WR, Gaab MR (2002) Complications of endoscopic third ventriculostomy. J Neurosurg 96:1032–1040
Teo C, Jones R (1996) Management of hydrocephalus by endoscopic third ventriculostomy in patients with myelomeningocele. Pediatr Neurosurg 25:57–63 discussion 63
Teo C, Rahman S, Boop FA, Cherny B (1996) Complications of endoscopic neurosurgery. Childs Nerv Syst 12:248–253 discussion 253
Thomson S, Tyagi AK, Chumas PD (2003) Intracranial hypertrophic calcification complicating neuroendoscopy. Report of three cases. J Neurosurg 98:186–189
Vaicys C, Fried A (2000) Transient hyponatriemia complicated by seizures after endoscopic third ventriculostomy. Minim Invasive Neurosurg 43:190–191
van Beijnum J, Hanlo PW, Fischer K, Majidpour MM, Kortekaas MF, Verdaasdonk RM, Vandertop WP (2008) Laser-assisted endoscopic third ventriculostomy: long-term results in a series of 202 patients. Neurosurgery 62:437–443 discussion 443–444
Wellons JC 3rd, Bagley CA, George TM (1999) A simple and safe technique for endoscopic third ventriculocisternostomy. Pediatr Neurosurg 30:219–223