ELSEVIER
SAUNDERS

Neurosurg Clin N Am 15 (2004) 61–66

NEUROSURGERY
CLINICS
OF NORTH AMERICA

Complications of third ventriculostomy

Marion L. Walker, MD

Primary Children's Medical Center, 100 North Medical Drive, Salt Lake City, UT 84113, USA

Improvements in instrumentation and growing experience with neuroendoscopy have made it possible to perform endoscopic third ventriculostomy (ETV) safely in a selected group of patients. The complication rate for ETV now approaches the rate for ventriculoscopy in general, approximately 6% to 8%, and is similar to the expected infection rate of shunts [1,2]. Although the exposure to significant neurologic complications is higher than the risk of a single shunt operation, the possibility of achieving long-term shunt independence with ETV is preferable in good-risk patients when compared with the cumulative morbidity of multiple shunt procedures [3–6]. The collective morbidity for a ventriculoperitoneal shunt is difficult to quantify; however, a recent prospective multicenter study of children undergoing their initial shunt insertion found that 31% had shunt obstruction, 3% had overdrainage, and 8% had infection within 1 year [1]. There is a 60% failure rate at 2 years.

Many of the complications of ETV are transient in nature. Skilled management of intraoperative problems can keep these complications limited to the intraoperative or perioperative period. At least one author has suggested categorizing complications as "clinically insignificant" and "clinically significant" [2]. Although this system may reflect the long-term outcome of the patient, the most important consideration, it does not emphasize the potentially devastating consequences of seemingly minor intraoperative events. This article seeks to define the most common potential complications of ETV and to identify factors in the pre-, intra-, and postoperative periods that can minimize their occurrence or effects.

Complications of endoscopic third ventriculostomy

Cerebrospinal fluid leak

Although rarely reported, cerebrospinal fluid (CSF) leakage can delay wound healing and increase the risk of infection. The possibility of a CSF leak may be minimized by using the smallest appropriate endoscope (especially in patients with large ventricles) and by minimizing the dural opening. A layered closure of the scalp is necessary. More importantly, however, a CSF leak is frequently a sign of failure of the third ventriculostomy, and close observation for this possibility is required.

Pneumocephalus

Often considered a minor or insignificant complication, pneumocephalus can delay postoperative recovery and can be associated with headache, nausea, and vomiting. Entrapment of air at the time of surgery can interfere with direct visualization of the anatomic landmarks that are essential to performing a third ventriculostomy safely. This can be minimized by keeping the patient's head in a midline anatomic position with the burr hole at or near the most superior point, by carefully flushing all irrigation lines of air bubbles, and by irrigating gently while introducing the endoscope. Attention should be paid to minimizing CSF loss, especially in the early stages of the procedure. Decompression of the ventricular system too rapidly can contribute to the formation of a subdural hematoma. Nitrous oxide should not be used for anesthesia during ETV because of the potential for formation of tension pneumocephalus.

Ventriculitis

Fever after ETV is not uncommon. In most cases, it is caused by residual blood in the

E-mail address: marion.walker@hsc.utah.edu

doi:10.1016/S1042-3680(03)00070-6

ventricular system. In this setting, fever is self-limited and lasts 24 to 48 hours. In some cases, postoperative fever has been attributed to raising the temperature of the CSF in the third ventricle when employing cautery or laser energy, indirectly heating the hypothalamus. Fever may also herald infection and should be monitored closely with analysis and culture of the CSF [7,8]. Fukuhara et al [9] report multiple cases in which preexisting ventricular shunt hardware was found to harbor infection after ETV. We believe that it is important to remove all shunt hardware after ETV whenever possible.

Careful and thorough sterilization of the endoscopic equipment and the use of perioperative antibiotics can minimize the occurrence of infection. Prompt diagnosis and treatment of ventriculitis are essential.

Subdural hematoma

Subdural hematoma has been reported after ETV [9]. Significant ventricular dilatation with a thin cortical mantle is a risk factor for subdural hemorrhage. Efforts should be made to avoid rapid drainage of large quantities of CSF, and lost CSF should be replaced with lactated Ringer's solution.

Injury to periventricular structures

The floor of the third ventricle is not a membrane but a part of the hypothalamus. It is apparently safe to puncture the floor of the third ventricle but only when it is thinned as a result of the pressure of hydrocephalus. Amenorrhea, diabetes insipidus, loss of thirst, and increased appetite have been reported after ETV [2,10,11]. Irrigation solution can also be the cause of complications. Generous irrigation with normal saline solutions has been associated with disturbance of electrolytes and hypothalamic dysfunction. Late arousal and postoperative confusion have also been noted [2]. These complications are caused by trauma to sensitive hypothalamic structures comprising the walls and floor of the third ventricle.

Several strategies can minimize injury to sensitive brain structures in the periventricular region. Careful preoperative evaluation may exclude patients with a narrow third ventricle; some authors have suggested a minimum third ventricular width of 7 to 10 mm [12,13]. Third ventriculostomy can be performed in small third ventricles, but this increases the risk of injury and should be attempted only in unusual circumstances and by experienced endoscopists. As experience has grown, the range of patients suitable for third ventriculostomy has widened. A number of surgeons have performed third ventriculostomy in patients with slit ventricle syndrome, with good results [14,15]. Modern stereotactic systems and small endoscopes have added a significant margin of safety to the procedure when it is performed in a narrow ventricular system.

Positioning of the patient is crucial; we advocate keeping the head in a midline position to simplify the surgeon's visualization of the anatomic landmarks. In a small space, such as the third ventricle, disorientation can quickly lead to injury of the hypothalamic structures or the fornix.

Planning of the incision and placement of the burr hole also play important roles in avoiding parenchymal injury; a narrow third ventricle demands a more medially placed burr hole, with a slightly more vertical trajectory (Fig. 1). Knowledge of the relevant anatomy is crucial because it allows the trajectory of the endoscope to be visualized before surgery and the procedure to be mentally "rehearsed" before making the incision. Once the patient is draped, the surgeon loses access to most of the external landmarks that define the trajectory of the endoscope and reorientation may be difficult.

During surgery, emphasis must be placed on controlled efficient movement of the endoscope with constant identification of anatomically relevant structures. When using small endoscopes without a working channel, we place a peel-away

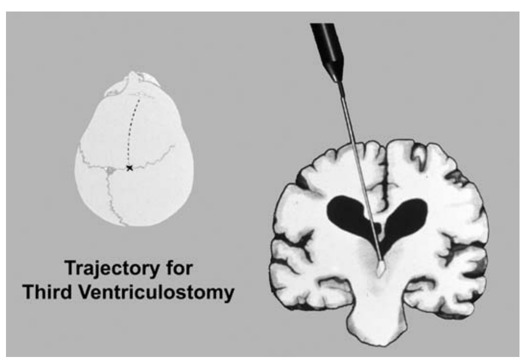

Fig. 1. An artist's illustration of the proper approach angle for endoscopic third ventriculostomy. The burr hole is made at the coronal suture in the midpupillary line. This provides an appropriate angle of approach through the foramen of Monro to the floor of the third ventricle.

sheath through the foramen of Monro under direct visualization; this prevents injury to the structures surrounding the foramen during removal and reinsertion of the endoscope and allows passage of instruments into the operative area without risk of injury to adjacent structures.

Familiarity with the particular endoscope in use is essential. When conditions conspire to make visualization or perforation of the floor of the third ventricle difficult, there should be a low threshold for abandoning the procedure. This is considered minimally invasive surgery; another attempt can be made at a later time, or a shunt can be placed.

Bradycardia/asystole

Several authors have reported transient bradycardia or asystole when perforating the floor of the third ventricle or while enlarging the ventriculostomy [2,7,9,16]. This is presumably caused by a direct mechanical effect on the hypothalamus or as the effect of irrigation. Irrigation fluid can be trapped in the third ventricle if the endoscope fills the foramen of Monro, and the addition of a seemingly insignificant volume may cause a dramatic increase in pressure. Handler et al [16] reported a ventricular arrhythmia progressing to asystole while irrigating with the endoscope in the third ventricle. This was believed to be consistent with expansion of the third ventricle while the endoscope prevented egress of fluid through the foramen of Monro. Prevention of these intraoperative complications lies in limiting the rate of irrigation, especially in the third ventricle, and in leaving one port of the endoscope open for the egress of fluid. Management consists of ceasing irrigation and withdrawing the endoscope until the patient is hemodynamically stable.

Vascular complications

Minor bleeding that is easily controlled with irrigation is common during ETV. Teo et al [2] reported ‘‘clinically insignificant’’ hemorrhage in 6 of 55 endoscopic ventriculostomies. Of 98 cases, Hopf et al [8] reported venous bleeding in 3 cases, arterial bleeding in 1 case, and 1 case in which there was bleeding from a bridging vein during the opening. Fukuhara et al [9] reported intraventricular hemorrhage necessitating placement of External Ventricular Drainage in 2 of 89 cases.

Small vessels may be encountered within the floor of the third ventricle. This type of bleeding can often be controlled with patience and continued irrigation. Brisk bleeding may also be encountered after injury to intraventricular veins and to perforating arteries and bridging veins in the interpeduncular cistern. Brisk bleeding requires significant irrigation and may require abandonment of the procedure. A pathway for CSF to exit is crucial in this circumstance.

Without a doubt, the most important and potentially devastating complication of ETV is injury to the basilar, posterior cerebral, or posterior communicating arteries. After arterial injury, major hemorrhage, vasospasm, pseudoaneurysm, and delayed subarachnoid hemorrhage have been reported, with significant morbidity and mortality (Fig. 2) [17–19]. Although the reported incidence is low, this author is aware of other as yet unreported cases. Because the consequences of arterial injury are so profound, it is essential to inform patients and their parents that major arterial injury is a real possibility.

Avoidance of hemorrhage is of utmost importance. Careful patient evaluation and selection may exclude patients at high risk or at least alert the surgeon to the specific risk factors. MRI and MR angiography are useful not only to establish the third ventricular anatomy but may demonstrate the location of the basilar artery in relation to the floor. During the procedure, the anatomy of the floor of the third ventricle must be carefully analyzed. The floor may appear opaque, and in

Fig. 2. Anteroposterior view of a basilar artery angiogram demonstrating a pseudoaneurysm of the posterior communicating artery at the junction with the basilar artery. This aneurysm created by injury to the basilar artery during endoscopic third ventriculostomy was successfully treated.

some cases, especially in myelomeningocele patients, the walls of the hypothalamus may be partially or entirely fused. If an area of thinning of the floor can be identified, the procedure can be performed; the risk, however, is increased with abnormal anatomy, and under such conditions, only an experienced endoscopist should attempt the procedure. A microvascular Doppler probe has been employed successfully in some cases to pinpoint the location of the basilar artery through an opaque floor [20,21].

The management of most intraoperative hemorrhage consists of irrigation and patience, as previously noted. Electrocautery is rarely helpful and is certainly dangerous in cramped ventricular spaces. In certain instances where the source of bleeding is in the floor of the third ventricle at the site of fenestration, a balloon catheter can be used to apply hemostatic pressure to the bleeding tissue.

In our reported case of basilar artery injury, the patient made a full recovery [17]. We believe this was in large part a result of the fact that we had positioned the tip of the peel-away sheath within the third ventricle, allowing the arterial blood to exit the sheath instead of filling the ventricular system. An external ventricular catheter should be placed if any significant intraventricular hemorrhage has occurred. A cerebral angiogram should be obtained within 1 to 3 days of any significant hemorrhage to rule out a pseudoaneurysm.

Intraoperative bleeding is difficult to quantify as to its significance, and there seem to be differing opinions in the literature regarding what constitutes "reportable" bleeding. It is essential for the further refinement of this technique that hemorrhagic complications be reported.

Failure of third ventriculostomy

The success of third ventriculostomy lies in large part in selecting patients whose CSF physiology can respond favorably to the procedure. Initially, the procedure was performed primarily for late-onset aqueductal stenosis, with good results [22]. As familiarity with the technique has grown, the indications have broadened and patients with noncommunicating hydrocephalus resulting from early-onset aqueductal stenosis, posterior fossa masses, tectal plate tumors, and myelomeningocele have been included as well as younger patients [7,23–27].

A recent review found that a history of shunt infection and postoperative meningitis were independent risk factors for ventriculostomy failure and that nearly half of ETV failures occurred within 2 weeks of the procedure, with only 3 of 89 cases failing more than 10 months after ETV [7]. It has been suggested that delayed failures are most often a result of closure of the ventriculostomy and can be managed by repeating the procedure [23].

Basic principles of complication avoidance

Patient selection

As experience has grown and the technique has been refined, third ventriculostomy has been performed successfully and safely in patients with obstructive hydrocephalus associated with aqueductal stenosis, posterior fossa masses, tectal plate tumors, myelomeningocele, and slit ventricle syndrome (Fig. 3). Relative contraindications, however, such as postinfectious and posthemorrhagic hydrocephalus, still exist. It is up to the surgeon to match his or her level of experience, skill, and confidence with the patient's anatomy and to inform the patient and family of the risks accordingly. For example, it may be appropriate in certain circumstances to offer ETV to a patient with hydrocephalus secondary to prematurity and intraventricular hemorrhage. The family should be aware that the procedure has a significantly

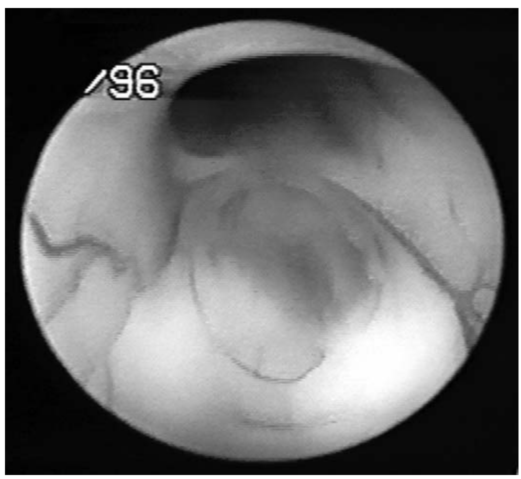

Fig. 3. An endoscopic view of the floor of the third ventricle in a patient with myelomeningocele. Almost complete fusion of the floor of the third ventricle is present. The mamillary bodies are not identifiable. There is thinning of the floor in two areas. Successful endoscopic third ventriculostomy was accomplished through the most posterior area of thinning.

less chance of success, however. In these patients, preoperative MRI should play a large role in determining the patient's suitability for the procedure.

Proper training

Manipulating the endoscope is a learned skill and one for which there can be a steep learning curve. Familiarity with the endoscope, knowledge of the relevant anatomy, and preoperative visualization of the trajectory are important factors in avoiding complications. We are now in an era when computer modeling of surgical procedures is possible, and this resource will play an increasingly important role in training for ETV.

Positioning

Proper positioning of the patient is crucial to maintain orientation during the procedure. The head should be in the midline position and slightly elevated. The burr hole should be placed with the final trajectory in mind, and the anatomy and trajectory should be visualized before the patient is covered by surgical drapes (see Fig. 1).

Endoscopic equipment

The endoscope with the smallest diameter appropriate to the patient should be chosen. The method of perforation of the floor is a subject on which there are many differing opinions. The most popular method is to use a pointed (but not sharp) instrument to open the floor and then to expand the opening with a balloon. We firmly believe that laser, cautery, and other forms of energy should not be employed because they significantly increase the risk of arterial injury [17,18].

Intraoperative management of complications

Irrigation and patience are the two most important methods for achieving hemostasis during ETV. The surgeon should also remember that ETV is a minimally invasive procedure and should be abandoned if conditions (eg, bleeding, unfavorable anatomy) conspire to make fenestrating the floor too dangerous. If significant bleeding occurs, an external ventricular drain should be left in place at the close of the procedure.

Postoperative management

In our experience, intracranial pressure remains elevated for 24 to 48 hours after ETV, especially in previously shunted patients whose shunts have been removed. With the exception of infants, we prefer to leave an external ventricular drain in place and monitor the patient in the intensive care unit after surgery.

Summary

As experience with ETV grows, the procedure will be performed by an increasing number of neurosurgeons. Although the technique has been greatly refined since its advent almost a century ago, today's neurosurgeon must never forget that this seemingly simple procedure holds the potential for a number of devastating complications. Appropriate training and experience are important to the success of ETV and for avoiding complications It is imperative that surgeons continue to report their experience with the complications of ETV so that the procedure can continue to be made as safe as possible.

References

[1] Drake J, Kestle J, Milner R, Cinalli G, Boop F, Piatt J, et al. Randomized trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus. Neurosurgery 1998;43:294–303.

[2] Teo C, Rahman S, Boop FA, Cherny B. Complications of endoscopic neurosurgery. Childs Nerv Syst 1996;12:248–53.

[3] Guzelbag E, Ersahin Y, Mutluer S. Cerebrospinal fluid shunt complications. Turk J Pediatr 1997;39: 363–71.

[4] Iskandar B, Tubbs S, Mapstone T, Grabb P, Bartolucci A, Oakes W. Death in shunted hydrocephalic children in the 1990s. Pediatr Neurosurg 1998;28:173–6.

[5] Lazareff J, Peacock W, Holly L, Halen JV, Wong A, Olmstead C. Multiple shunt failures: an analysis of relevant factors. Childs Nerv Syst 1998;14:271–5.

[6] Lee JY, Wang KC, Cho BK. Functioning periods and complications of 246 cerebrospinal fluid shunting procedures in 208 children. J Korean Med Sci 1995;10:275–80.

[7] Brockmeyer D, Abtin K, Carey L, Walker M. Endoscopic third ventriculostomy: an outcome analysis. Pediatr Neurosurg 1998;28:236–40.

[8] Hopf NJ, Grunert P, Fries G, Resch KD, Perneczky A. Endoscopic third ventriculostomy: outcome analysis of 100 consecutive procedures [see comments]. Neurosurgery 1999;44:795–806.

[9] Fukuhara T, Vorster S, Luciano M. Risk factors for failure of endoscopic third ventriculostomy for obstructive hydrocephalus. Neurosurgery 2000;46: 1100–9.

[10] Drake JM. Ventriculostomy for treatment of hydrocephalus. Neurosurg Clin North Am 1993;4:657–66.

[11] Lowry D, Lowry D, Berga S, Adelson P, Roberts M. Secondary amenorrhea due to hydrocephalus treated with endoscopic ventriculocisternostomy. Case report. J Neurosurg 1996;85:1148–52.

[12] Hoffman HJ, Harwood-Nash D, Gilday DL. Percutaneous third ventriculostomy in the management of noncommunicating hydrocephalus. Neurosurgery 1980;7:313–21.

[13] Jones R, Stening W, Brydon M. Endoscopic third ventriculostomy. Neurosurgery 1990;26:86–91.

[14] Baskin JJ, Manwaring KH, Rekate HL. Ventricular shunt removal: the ultimate treatment of the slit ventricle syndrome. J Neurosurg 1998;88:478–84.

[15] Reddy K, Fewer HD, West M, Hill NC. Slit ventricle syndrome with aqueduct stenosis: third ventriculostomy as definitive treatment [see comments]. Neurosurgery 1988;23:756–9.

[16] Handler MH, Abbott R, Lee M. A near-fatal complication of endoscopic third ventriculostomy: case report. Neurosurgery 1994;35:525–8.

[17] Abtin K, Thompson B, Walker M. Basilar artery perforation as a complication of endoscopic third ventriculostomy. Pediatr Neurosurg 1998;28:35–41.

[18] McLaughlin M, Wahlig J, Kaufman A, Albright A. Traumatic basilar aneurysm after endoscopic third ventriculostomy: case report. Neurosurgery 1997; 41:1400–3.

[19] Schroeder HW, Warzok RW, Assaf JA, Gaab MR. Fatal subarachnoid hemorrhage after endoscopic third ventriculostomy. Case report. J Neurosurg 1999;90:153–5.

[20] Cartmill M, Vloeberghs M. The use of transendoscopic Doppler ultrasound as a safety-enhancing measure during neuroendoscopic third ventriculostomy. Eur J Pediatr Surg Suppl 1999;1: 50–1.

[21] Schmidt R. Use of microvascular Doppler probe to avoid basilar artery injury during endoscopic third ventriculostomy. J Neurosurg 1999;90:156–8.

[22] Hirsch J, Hirsch E, Sainte-Rose C, Renier D, Pierre-Kahn A. Stenosis of the aqueduct of Sylvius. Etiology and treatment. J Neurosurg Sci 1986;30: 29–39.

[23] Cinalli G, Sainte-Rose C, Chumas P, Zerah M, Brunelle F, Lot G, et al. Failure of third ventriculostomy in the treatment of aqueductal stenosis in children. J Neurosurg 1999;90:448–54.

[24] Cinalli G, Salazar C, Mallucci C, Yada JZ, Zerah M, Sainte-Rose C. The role of endoscopic third ventriculostomy in the management of shunt malfunction. Neurosurgery 1998;43:1323–9.

[25] Jones R, Kwok B, Stening W, Vonau M. The current status of endoscopic third ventriculostomy in the management of non-communicating hydrocephalus. Minim Invasive Neurosurg 1994;37: 28–36.

[26] Jones R, Kwok B, Stening W, Vonau M. Third ventriculostomy for hydrocephalus associated with spinal dysraphism: indications and contraindications. Eur J Pediatr Surg 1996;6:5–6.

[27] Teo C, Jones R. Management of hydrocephalus by endoscopic third ventriculostomy in patients with myelomeningocele. Pediatr Neurosurg 1996;25: 57–63.