Egyptian Journal of Neurosurgery

REVIEW

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Endoscopic third ventriculostomy complications: avoidance and management in a stepwise manner

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Abstract

Background: Various complications of endoscopic third ventriculostomy (ETV) have been described. One has to recognize these complications and learn how to avoid them.

Methods: We performed a literature review regarding the reported complications of ETV procedures discussed in a correlated manner with the surgical steps. Furthermore, we reviewed the technical notes described by experienced neuroendoscopists, including surgical indications, choice of the endoscopic entry point and trajectory, anatomic orientation, proper bleeding control and tight closure, to prevent and deal with such complications.

Results and conclusion: A lesson learned that comprehensive knowledge of ventricular anatomy with proper orientation by studying the preoperative images is mandatory and one should be aware of all complication types and rates.

Keywords: Ventriculostomy, Endoscopic, Complications, Avoidance, Management

Background

Endoscopic third ventriculostomy (ETV) is a procedure whereby a small ostium is created in the floor of the third ventricle as a therapeutic measure to alleviate the symptoms of hydrocephalus [1]. Debate still exists regarding selection of proper candidates for ETV and the prediction of its success score [2].

The majority of ETV complications are centered around the procedure itself. The overall morbidity rate reported to range from 0 to 31.2%, the overall rate of permanent morbidity is 2.38% and mortality ranges between 0.28% and 1.28% [3–5].

Some examples of such dreadful complications include meningitis, sepsis, thalamic injury, basilar artery injury. One of the major contributors to failure is loss of anatomical orientation which is frequently the result of altered anatomy caused by many diseases [6]. Examples of such challenging diseases are those caused by developmental anomalies such as myelomeningocele and multilocular hydrocephalus, neoplasm arising from basal ganglia and large thalamic tumors; in such circumstances, it is difficult to identify the transparent membrane in front of the mammillary bodies [5, 7, 8]. Injury to the basilar artery or its perforators is seen in the settings of a thickened 3rd ventricular floor and following the treatment of ventriculitis, whereby the basilar artery and its perforators do not come easily into view leading to an uncontrolled perforation of the floor and a concomitant injury [4]. Careful assessment of preoperative magnetic resonance imaging (MRI) of the brain is imperative to assess the trajectory, ventricular access and size and the space available between the clivus and mammillary bodies. Repeated ETVs as with other neurosurgical

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procedures have also been associated with increased risk of complications [7, 9].

It is thought that complications of ETV is underrated some of which may have not been recognized to be attributed to the insult. For example, cardiac arrhythmias can occur when there is injury to hypothalamic–pituitary axis structures near the floor of the third ventricles [3, 4, 6, 7, 10].

This article reviews various types of complications reported in studies including the rare ones and discusses the possible strategies to avoid these serious complications.

Methods

The PubMed database was searched for publications through using the MeSH terms (endoscopic third ventriculostomy OR ETV AND complication OR avoidance OR prevention AND management of ETV). The search included articles in the English, German and French languages. All reference sections were manually reviewed and pertinent articles identified. Initially, relevant articles were retrieved in either title or abstract format and full-text manuscripts were subsequently collected for all original articles related to current study. A total of 261 studies were reviewed and 26 studies were selected in this review.

Results

Intraoperative complications

Complications during opening and entrance of the lateral ventricle

The majority are caused by minor bleeding from stretching of veins, or violation of the small cortical, parenchymal or ependyma vessels by the endoscopic device, which occurs in up to 16.5% of cases [3, 5]. These, from our point of view, are easily controlled using continuous irrigation and gentle compression [11].

Complications during passage through foramen of Monro

Septal and thalamostriate veins must be always respected as major bleeding is reported in 0.49% [11]. Although unilateral injury of the fornix is tolerated to some degree, care must be taken to avoid forniceal injury during passage of the endoscope in and out of the foramen of Monro to avoid any postoperative short memory deficit [4].

Complications during passage through third ventricle

Inadvertent entry into thalamus may cause thalamic infarcts and postoperative sensory disorders [4, 10].

Complications during perforation of the floor of third ventricle

Injury to the basilar artery Basilar artery course should be carefully studied on preoperative images, and attention should be paid to whether its apex is abutting the floor of the 3rd ventricle or not as this may increase the risk of injury to the basilar or its perforators which can occur in 0.2–0.3% of cases [3, 12, 13]. Similarly, an opaque floor and thick Liliequist's membrane are risk factors for such injury [14].

Injury to the hypothalamus Improper ostomy location may lead impaired cognition, weight gain, precocious puberty [4, 10]. Similarly, intraoperative bradycardia can manifest from the inadvertent injury to the posterior hypothalamus [15].

Injury to third and six cranial nerves Third and six cranial nerves run near the floor of the third ventricle, and therefore, the surgeon must keep in mind the important anatomical structures in and around the floor of the third ventricle as inadvertent injury either by stretching the nerve during the process of dilating the ostium or by direct injury may lead to ocular movement abnormalities manifested immediately in the postoperative period in the form of transient ocular divergence and anisocoria [4, 10].

Injury to Infundibulum stalk Although morbidity is low < 1%, however, one must ensure to avoid creating an ostium close to infundibular recess as this may cause permanent diabetes insipidus with associated loss of thirst. The tuber cinereum is an extension of the hypothalamic–pituitary axis and regulates hormonal functions within the body, estimated incidence of diabetes insipidus (0.64%), weight gain (0.27%) and precocious puberty (0.04%). Transient electrolyte disturbances such as hyponatremia, hypernatremia and hyperkalemia can also occur [3, 4, 7, 16, 17].

Complication due to unbalanced irrigation/drainage

Cerebral herniation syndrome There must be a balance between the volume of irrigation and outflow. Excessive irrigation will cause changes related to intracranial pressure (ICP) which may cause delayed awakening and postoperative confusion [7].

Hemodynamic changes Rare reports of intraoperative asystole and hemodynamic changes have been reported. Hemodynamic changes not necessarily include bradycardia and hypertension but also tachycardia [5, 15]. It is imperative to hold any surgical maneuvers such as ballooning, irrigation, endoscope manipulation when hemodynamic changes are noticed. Re-assessment of irrigation outflow patency and speed of irrigation should be promptly done as majority of these changes are due to a sudden increase in the ICP and impaired cerebral perfusion [5].

Postoperative complication

Neuronal injury is related to the technique of handling the endoscope in and out, the trajectory chosen and the underlying pathology. Inadvertent injury is commonly seen with memory impairment and neurocognitive changes [18]. Such changes can be transient or permanent, 2.0, 1.04%, respectively. Other injuries may cause decreased level of consciousness, confusion, convulsions. In a series of sixty patients, early convulsions are seen in 6.7% and late convulsions 8.3%. Those with early convulsions were at an increased risk for convulsions later (75% vs. 3.7%, $p = 0.003$) [19].

Postoperative hemorrhage

Postoperative hemorrhage (including subdural, intracerebral and epidural hematomas) is reported to be 5% in a large study [3].

Cerebrospinal fluid (CSF) leak

CSF leak is generally a sign of treatment failure, and it has a reported incidence ranging between 1.7% and 5.2% [4]. It is important to block the tract of the endoscope with a piece of Gelfoam before closure; application of additional sutures and lumbar puncture or a drain have been shown to be effective measures when CSF leak occurs postoperatively [8].

Central fever

Typically, central fever starts on postoperative day 1 and then quickly subsides within 3 days with an estimate reports 65% to 84% [20] mostly in children. It is thought to be caused by mechanical manipulation of the hypothalamus, bleeding and air inside the ventricle; however, infections should be sought initially until proven otherwise [21].

Infection

Meningitis or ventriculitis is frequently encountered postoperatively in association with CSF leakage. Incidence ranges between 2 and 6% and can rarely progress into sepsis when antibiotics are administered in a timely fashion [3, 4].

Sudden death due to closure of the stoma

Acute hydrocephalus resulting from reclosure of the stoma can be a source of morbidity and mortality [22, 23]. Sudden death, although exceedingly rare, reported in 0.07%. This is true especially when the diagnosis of ETV failure is difficult and unpredictable given the ambiguity of the ICP symptoms associated with it and the delays found in obtaining MRIs with CSF flow studies [3].

Discussion

Prevention of complications

Proper surgical indication

In general, there is more risk associated with ETV compared to shunting in terms of neural injury. Good preoperative planning, avoidance of multiple ETV trials and prediction of ETV success are essential prerequisites for a successful ETV [8].

Proper selection of the entry point of ventricular entry

Entry point should be based on the size and configuration of the ventricles of the patient. Typical location is at or just in front of the coronal suture in the midpapillary line, more or less, similar to that of Kocher's point. It is important to maintain straight trajectory as much as possible to the foramen of Monro and floor of the third ventricle [8, 24].

Modification of entry point is particularly important in cases where ETV and biopsy are simultaneously required such as in cases of pineal region tumors that extend into the 3rd ventricle. Advancement in neuroendoscopy has allowed safe procedures to be done with flexible working angles; the availability of neuronavigation is particularly important in helping to select the appropriate and safe trajectory [24]. Likewise, flexible endoscope is especially helpful for tumors in the posterior third of 3rd ventricle. Either single or double burr holes are acceptable options [25]. We prefer biportal trajectory with rigid endoscopy to perform the two procedures (Fig. 1). Because of possible bleeding from the tumor, we perform the ETV first and then perform the biopsy later [26].

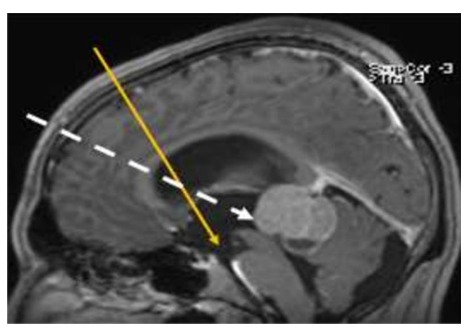

Fig. 1 Preoperative sagittal T1 MRI with contrast showing the trajectory for an ETV (yellow arrow) and the trajectory for pineal region tumor biopsy (white dotted arrow)

Proper insertion of the endoscope

Nowadays, endoscopes have become smaller in diameter compared to the past; despite their small diameter, they are still larger than a shunt catheter and may cause significant neuronal injury if not placed correctly. Preoperative ventricular measurement is important to gauge the feasibility of ventricular cannulation. If the ventricular size is relatively small, intraoperative image guidance or intraoperative ultrasound as an alternatively is fundamental tools for a proper ventricular access. If ventricular size is moderate or large, ventricular puncture can usually be done safely with careful aiming of the endoscope based on preoperative images [27].

Accurate anatomical orientation for steering of endoscopes

A common mistake encountered is entering too anteriorly in the frontal horn where it becomes difficult to find the choroid plexus which emanate from foramen of Monro and run posteriorly; in such cases, the endoscope should steered posteriorly. Septal defects are not unusual particularly in chronic or congenital hydrocephalus [28].

It is important to identify anatomical landmarks early to make a proper orientation. Such anatomical structures include Monro, septal veins, thalamostriate veins and the choroid plexus. The dorsum sella and at times tip of basilar artery can be seen through the relatively thin and transparent floor of the 3rd ventricle. However, in cases where there were a chronic inflammation and congenital anomalies as is seen in myelomeningocele, these easy landmarks can be distorted. It is important to step back and appreciate the surrounding anatomical structures to orient oneself before advancing further [6].

Meticulous preoperative inspection of magnetic resonance images to evaluate the position of the basilar artery in relation to the floor of the third ventricle is important given the anatomical variations [29, 30].

Skillful passing of an endoscope through the foramen of Monro

Passage through the foramen of Monro is a very critical step and requires care as it is common to injure the fornix at this step of the procedure. In most circumstances, the injury is unilateral and minor which does not cause memory disturbance. However, if the injury is bilateral significant, postoperative memory disturbance can ensue.

If the ETV is to be done for a second time, it is important to choose the same entry through the foramen of Monro especially in cases where there has been a previous injury to the fornix [4].

The choroid plexus exiting the foramen of Monro can sometimes be large enough to obliterate the foramen of Monro. In this case, it is reasonable to coagulate the choroid plexus before passing the endoscope. In cases where the foramen of Monro is small, using fluid irrigation near the foramen may help to enlarge the foramen Monro [31]. Proper selection of the size of endoscope should be based on the assessment of the size of foramen of Monro in the preoperative MRI.

Proper insertion of instruments through the endoscopic port

It is important to note that there is 180° visual angle available. The ventricular outlet of the endoscope is at the same level as the optic fiber. Therefore, when passing instrument in and out of the endoscope, the endoscope must be retracted back for a short distance in order for the surgeon to see the tip of the instrument being inserted. Indiscriminate passing of instruments through the endoscope especially when the tip of the endoscope is near important neuronal structures will cause injury and bleeding. Although injury to the lateral ventricular wall is mostly benign, it may be a source of bleeding and may cause prolonged operative time. It is prudent to orient the tip of the endoscope slightly away from important structures until the tip of the inserted instrument is seen at which time then the endoscope can be advanced with the instrument as one piece [22].

Skillful penetration of the floor of the third ventricle

The point of perforation of the floor is in the midline and just anterior to the mammillary bodies (Fig. 2).

Technical note Multiple techniques can be used for perforating the floor of third ventricle. We use endoscopic grasping forceps to make the initial perforation. After perforation, the hole can be enlarged either by a Fogarty balloon catheter or endoscopic grasping forceps which should be inserted and then spread in the stoma.

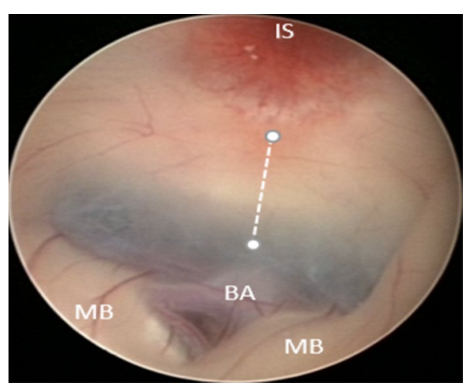

Fig. 2 Floor of 3rd ventricle showing the anatomical landmark for an ETV ostium (dotted white line). BA; basilar artery, IS; infundibulum stalk, MB; mammillary body

It is crucial to avoid closing the grasping forceps after the floor has been breached so that a penetrating vessel on the other side is not inadvertently grabbed; the forceps should be inserted through the hole, opened, and then withdrawn without closing them until the tips are directly visualized (Fig. 3). The stoma should be widened as much as possible without encroaching on the mammillary bodies, infundibular recess, or walls of the third ventricle. It is vital to confirm that the prepontine cistern has been entered. We should make sure that two layers have been penetrated, the tuber cinereum and the membrane of Liliequist. One source of procedure failure is penetrating the floor (tuber cinereum) but not adequately traversing the membrane. The surgeon should avoid endoscopic tourism after accomplishing the procedures to avoid any unexpected complication at the end of the procedure.

Thick and opaque membrane

It is not unusual to encounter a thick and opaque membrane. This causes a challenge and requires high level of expertise. Water jet dissection technique has been described to reduce risk of bleeding and neurological deficits when thick and cloudy membranes are encountered [14].

It is always prudent to remember the ethical principle of "do no harm"; therefore, in such circumstances where the surgeon faces tough 3rd ventricular floor membrane, it is wise to abandon the procedure especially when there is disorientation or a higher risk of complications. Attempting to pass through such membranes will cause unnecessary bleeding, stretching of adjacent critical neuronal structures, or may simply not be amenable to perforation. Other CSF diversion techniques may be sought such as ventriculoperitoneal shunt.

Adequate control of bleeding

Bleeding sources inside ventricles usually come from small capillaries, choroid plexus, veins which are commonly encountered during ventricular endoscopic access. The most common way of controlling bleeding from these vessels is by using continuous saline irrigation, which not only will clear the operative field but also will stop the bleeding. Although washing itself is less effective in controlling the bleeding, the pressure component exerted by the fluid of the saline irrigation is what allows bleeding to stop. This fluid column pressure effect can be augmented effectively by closing the drainage port for as long as 4–5 min while alerting the anesthetic staff to be vigilant for any hemodynamic changes and to avoid the unwanted high pressure that may cause ischemic damage [11]. Major bleeding is a rare occurrence and usually occurs from basilar perforators at the stoma site [32], and the tear in the arterial wall is thought to be small; however, it takes much longer time to control, wash-out with large amount of saline irrigation is required, and follow-up angiography is important to rule out pseudoaneurysm which may require neurointerventional procedures [12, 13]. Some authors described the small-chamber irrigation technique as a simple maneuver for managing intraoperative hemorrhage during endoscopic intraventricular surgery [33]. Nagasaki et al. reported a balanced irrigation–suction technique with a multifunctional suction cannula for intraoperative hemorrhage during ventricular endoscopy [34]. The dry field technique was described by many authors as a last resort to deal with intraoperative hemorrhage during ventricular endoscopy [35].

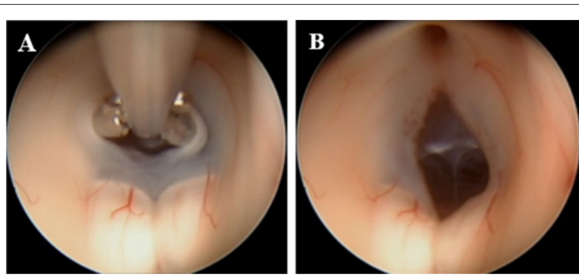

Fig. 3 **A**: Techniques of widening the stoma, **B**: the stoma after being widened by grasping forceps

Precaution to prevent postoperative CSF leakage in infants

Underdevelopment of CSF absorption pathways in infants as compared to older children increases the failure rate of ETV, leading to a major surgical concern and conversion to shunting procedures [36]. Moreover, the dura and galea are weaker and thin in small children which adds another challenge to getting a watertight closure. The most important step is to plug the tract of the endoscope with piece of tapered Gelfoam fashioned in a way that it does not slip into the ventricle. Enforcement of the wound is another way to prevent CSF leak and pseudomeningocele formation. If possible and in case where a large burr hole was created, closure of the dura can be attempted. It is important to make use of the pericranium as well that overlies the burr hole. In addition, using dural sealants or bone dust to plug the burr hole with the addition a titanium burr hole cover as a support will also help facilitate tight closure [37, 38].

Reclosure of the stoma

Early reclosure of the stoma is not common if the procedure was done correctly. Careful postoperative monitoring of the patient is required with a focus on ICP signs and symptoms. Early reclosure may be caused by low CSF pressure through the stoma which would in turn allow the stoma to fold on itself and close, or it may be due to incomplete opening of the floor of the third ventricle and or Liliequist's membrane. As a general rule of thumb, if the endoscope can pass through the ostium, the ostium is probably wide enough. Difficulty with fenestration of the Liliequist's membrane arises when the membrane itself is deep and pushed up against the clivus by the basilar artery making small corridor for the endoscope or the instruments to pass, or where there are perforators running through or adjacent to the Liliequist's membrane making its perforation risky. In such circumstances, the goal of the procedure would have not been established and it is wise to convert to other CSF diversion techniques such as ventriculoperitoneal shunting. A successful ETV indicator is to see the floor of the third ventricle flapping in synchrony with the diastolic and systolic waves. Parikh et al. [39] advocated placement of CSF reservoir following ETV for direct ventricular access in case early failure was anticipated and also for direct ICP measurement; however, we think that this defeats the purpose of ETV where the main purpose is avoiding implantable devices. Others have also performed stented ETV to maintain the patency of the created stoma in patients with a high likelihood of reclosure; however, more research is needed to establish its use [40–42].

Conclusions

- Proper surgical indication is the first step to avoid complications.
- Comprehensive knowledge of the ventricular anatomy with proper orientation of the landmarks as well as meticulous studying of the sagittal MRI is of paramount importance to avoid complications.
- Understanding of potential surgical complications at each step is crucial to prevent it.
- Careful intraoperative monitoring by anesthesiologist is necessary for early warning of the surgeon of hemodynamic instability that may occur at any stage of the procedure.
- Even though the complication rate of ETV is not so high, and the procedure is not so technically demanding, serious events can happen from unusual appearance of the third ventricular floor. Consequently, it is advisable that the procedure should always be done under supervision of a senior neuroendoscopist.

Abbreviations

ETV: Endoscopic third ventriculostomy; MRI: Magnetic resonance imaging; ICP: Intracranial pressure.

Acknowledgements

The authors would like to thank the patient for agreeing to publish the case for educational purposes.

Author contributions

AF contributed to conception or design of the work, data collection, data analysis and interpretation. RM responsible of statistical methods. All authors drafted the article, critically revised the article and contributed to study supervision, funding and materials. All authors reviewed the results and approved the final version of the manuscript.

Funding

Not applicable.

Availability of data and materials

Data are available upon request.

Declarations

Ethical approval and consent to participate

Ethical approval has been obtained from ethical board committee according to declaration of Helsinki.

Consent for publication

Consent has been obtained from the patient.

Competing interests

The authors declare no competing interests.

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Received: 17 May 2022 Accepted: 10 June 2022
Published online: 29 August 2022

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