Avoidance and management of perioperative complications of endoscopic third ventriculostomy: the Dhaka experience

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OBJECT Although endoscopic third ventriculostomy (ETV) is a minimally invasive procedure, serious perioperative complications may occur due to the unique surgical maneuvers involved. In this paper the authors report the complications of elective and emergency ETV and their surgical management in 412 patients from July 2006 to October 2012 at Dhaka Medical College Hospital (a government hospital) and other private hospitals in Dhaka, Bangladesh. The authors attempted some previously undescribed simple maneuvers that may help to overcome the difficulties of managing complications.

METHODS The complication rate was determined by recording intraoperative changes in pulse and blood pressure, bleeding episodes, serum electrolyte abnormalities, CSF leakage, and neurological deterioration in the immediate postoperative period.

RESULTS Intraoperative complications included hemodynamic alterations in the form of tachycardia, bradycardia, and hypertension. Bleeding was categorized as major in 2 cases and minor in 68 cases. Delayed recovery from anesthesia occurred in 14 cases, CSF leakage from the wound in 11 cases, and electrolyte imbalance in 5 cases. Postoperatively, 2 patients suffered convulsions and 1 had evidence of third cranial nerve injury. Three patients died as a result of complications.

CONCLUSIONS Complications during endoscopy can lead to serious consequences that may sometimes be very difficult to manage. The authors have identified and managed a large number of complications in this series, although the rate of complications is consistent with that in other reported series. These complications should be kept in mind perioperatively by both surgeons and anesthesiologists, as prompt detection and action can help minimize the risks associated with neuroendoscopic procedures.

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KEY WORDS endoscopy; third ventriculostomy; hydrocephalus; complications
Methods

Study Population

A consecutive series of patients undergoing elective and emergency neuroendoscopic surgery for the treatment of hydrocephalus and other intraventricular pathology treated by the same neurosurgical team between July 2006 and October 2012 were studied. Informed consent was obtained for every procedure.

Preoperative clinical assessment included documentation of neurological examination, ophthalmoscopic findings, and any prior shunt placement. During anesthesia, each patient was monitored by electrocardiography and pulse oximetry. Intraoperative intravenous fluid requirements were satisfied using Hartmann’s solution in adults and isotonic pediatric solution in children. After reversal of anesthesia, patients were closely monitored in the postoperative care unit for 4–5 hours.

Surgical Technique

For neuroendoscopy the patient was positioned supine with the head elevated to 20°–30° and with slight flexion of the neck. A bur hole was drilled at Kocher’s point, located 3 cm from the midline and 1 cm anterior to the coronal suture, approximately along the midpupillary line. A rigid neuroendoscope (Karl Storz) with a 6-mm sheath, working port, and 1.8-mm telescope was introduced into the lateral ventricle, where the choroid plexus could be seen (Fig. 1A). Continuous irrigation with Hartmann’s solution was started at 5–10 ml/min and the irrigation speed was increased if required. To keep the third ventricle slightly overfilled, we irrigated for a little while, usually not more than 15 seconds, without letting the fluid out.

The irrigation was monitored in the drip chamber. When it slowed or spontaneously stopped, it was assumed that the third ventricle was overfilled and fluid was released through the sheath. The endoscope was advanced through the foramen of Monro into the cavity of the third ventricle, where fenestration was planned. The ventricular floor was identified as a bluish transparent membrane in front of the mammillary bodies (Fig. 1B). Careful observation revealed basilar artery pulsations. Perforation of the third ventricle floor was performed in the midline between the infundibular recess and the mammillary bodies, with sustained pressure on the membrane by long third ventriculostomy forceps (Fig. 1C). The opening was dilated to 5–6 mm with a 3-Fr Fogarty balloon catheter. Adequacy of the ventriculostomy was judged by oscillations of CSF flow through the fenestration. The endoscope was inserted through this enlarged passageway into the prepontine space to explore the basilar artery and its tributaries. When a second membrane was observed (often connected to the Liliequist membrane in the prepontine space; Fig. 1D), this membrane was fenestrated with a blunt probe and enlarged with a Fogarty catheter. This step was performed to ensure that there was no other membrane obstructing

FIG. 1. Perioperative neuroendoscopic photographs. A: Within the right lateral ventricle, showing the choroid plexus and interventricular foramen of Monro. B: Mammillary bodies, in front of which the floor of the third ventricle is observed. C: A fenestration has been made in the floor of the third ventricle. D: Liliequist membrane following fenestration of the floor of the third ventricle. E: Balloon of the Fogarty catheter within the fenestration, applying sustained pressure to arrest the bleeding. F: Basilar artery and its bifurcation following fenestration of the floor of the third ventricle and Liliequist membrane. Figures are available in color online only.
free CSF flow in the prepontine space. The procedure was continuously displayed on a video screen. The color of the outflow fluid was noted and irrigation was continued until the fluid was colorless. On completion of the ventriculostomy, the neuroendoscope was withdrawn and the operative site was closed in layers.

**Complication Variables**

Changes in heart rate, rhythm, and mean arterial pressure were noted throughout the procedure by the anesthesiologists. Bradycardia and tachycardia were defined as decreases or increases in heart rate of 20% or more from baseline values, respectively. Hypotension or hypertension were defined as similar changes in mean arterial pressure of 20% or more from baseline values, respectively. Serum sodium and potassium values were monitored up to the first postoperative day. Hyponatremia and hypernatremia were defined as decreases or increases, respectively, in serum sodium values outside the normal range of 130–145 meq/L. Hypokalemia and hyperkalemia were defined as similar changes in serum potassium values outside 3.5–5 meq/L. Major bleeding was defined as that which significantly obscured endoscopic visibility and did not clear despite increased irrigation. Recovery from anesthesia was considered delayed if the patient’s consciousness did not revert to preoperative levels within 45 minutes of reversal of anesthesia.

**Results**

**Study Population Data**

Four hundred twelve cases were analyzed; of these, 224 involved male patients and 188 female patients. Three hundred twenty patients were less than 5 years of age, 60 were 5–18 years of age, and 32 were older than 18 years.

The majority of patients (n = 210) were treated for aqueductal stenosis. Other indications for ETV were hydrocephalus due to posterior fossa tumors or cysts, previous ventriculitis, posterior fossa hemorrhage, Chiari malformation, failure of ventriculoperitoneal shunting, congenital fourth ventricular outlet obstruction, and empty sella syndrome (Table 1).

The duration of surgery ranged from 10 minutes to 2 hours. Duration was measured from skin incision until skin closure. The very short procedures were uneventful operations in children with open anterior fontanelles in which the lateral aspect of the fontanelle was used to access the ventricle without the need for a bur hole. This happened in few cases, but the shortest time was recorded in only 2 cases.

**Complications and Management Strategies**

The complications are summarized in Table 2. Intraoperative tachycardia occurred in 32 patients, and was accompanied by hypertension in 19 patients. Bradycardia was observed in 23 patients, of whom only 2 patients had accompanying hypertension. Hypertension was noted in 21 patients associated with either bradycardia or tachycardia. In total, 17.96% of patients had transient intraoperative cardiovascular instability. When the surgeon was alerted to the event, surgery was paused and maneuvers such as releasing irrigation fluid, deflating the balloon, or withdrawing the endoscope resulted in prompt normalization of observed hemodynamic changes. All hemodynamic changes were transient, no drug treatment was required, and there was no postoperative morbidity related to these changes. No patient suffered an intraoperative cardiac arrest.

Major bleeding that significantly obscured the vision of the endoscope was encountered in 2 (0.49%) of 412 patients due to injury to branches of the basilar artery or large ependymal veins. Minor bleeding occurred in 68 patients (16.5%). Thirty-three patients experienced more than 1 complication. The majority of these complications were related to hemorrhage, followed by a cardiovascular response.

Three patients (0.73%) died postoperatively prior to hospital discharge. The cause of death was thalamic injury in 2 cases and basilar artery injury in the other case. All three patients died on the first postoperative day. In both cases of thalamic injury, the anatomy was not clear and the injury occurred due to positioning the endoscope too laterally within the ventricular cavity. To avoid this complication, we took several measures. From the beginning of the operation, we stressed the importance of positioning the patient and using the landmarks. Even in the presence of congenitally distorted anatomy it is important to start the operation with the available appropriate land-

**TABLE 1. Indications for ETV in this series of 412 patients**

<table>
<thead>
<tr>
<th>Indication</th>
<th>No. of Patients (%)</th>
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<tbody>
<tr>
<td>Aqueductal stenosis</td>
<td>210 (50.97)</td>
</tr>
<tr>
<td>Hydrocephalus due to posterior fossa tumors</td>
<td>74 (17.96)</td>
</tr>
<tr>
<td>Hydrocephalus due to cysts</td>
<td>56 (13.59)</td>
</tr>
<tr>
<td>Previous ventriculitis</td>
<td>49 (11.89)</td>
</tr>
<tr>
<td>Failure of ventriculoperitoneal shunt</td>
<td>8 (1.94)</td>
</tr>
<tr>
<td>Hydrocephalus due to posterior fossa hemorrhage</td>
<td>6 (1.46)</td>
</tr>
<tr>
<td>Hydrocephalus due to Chiari malformation</td>
<td>6 (1.46)</td>
</tr>
<tr>
<td>Congenital fourth ventricular outflow obstruction</td>
<td>2 (0.49)</td>
</tr>
<tr>
<td>Hydrocephalus w/ empty sella syndrome</td>
<td>1 (0.24)</td>
</tr>
</tbody>
</table>

**TABLE 2. Perioperative complications of ETV in 412 patients**

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%)</th>
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<tbody>
<tr>
<td>Major bleeding</td>
<td>2 (0.49)</td>
</tr>
<tr>
<td>Minor bleeding</td>
<td>68 (16.50)</td>
</tr>
<tr>
<td>Tachycardia</td>
<td>32 (7.78)</td>
</tr>
<tr>
<td>Bradycardia</td>
<td>23 (5.58)</td>
</tr>
<tr>
<td>Hypertension w/ tachycardia/bradycardia</td>
<td>19 (4.61)</td>
</tr>
<tr>
<td>Delayed recovery from anesthesia</td>
<td>14 (3.40)</td>
</tr>
<tr>
<td>CSF leakage</td>
<td>11 (2.67)</td>
</tr>
<tr>
<td>Electrolyte imbalance</td>
<td>5 (1.21)</td>
</tr>
<tr>
<td>Convulsion</td>
<td>2 (0.49)</td>
</tr>
<tr>
<td>Cranial nerve III palsy</td>
<td>1 (0.24)</td>
</tr>
<tr>
<td>Death</td>
<td>3 (0.73)</td>
</tr>
<tr>
<td>More than 1 complication</td>
<td>33 (8.01)</td>
</tr>
</tbody>
</table>
marks and trajectory. After entering the lateral ventricle, the choroid plexus should be used as a guide to safely enter the interventricular foramen of Monro, which will steer the surgeon into the third ventricle. Because the thalamus lies in the lateral wall of the third ventricle, the endoscope should be directed medially rather than laterally. Obviously, directing the endoscope toward the septum pellucidum is safer than directing it toward the thalamus.

The third death, in a patient with a basilar artery injury, was attributed to poor visibility as a result of bleeding from minor vessels. We attempted to fenestrate Liliquist’s membrane, but the basilar artery was injured. We placed an external ventricular drain, but the patient died. To avoid these complications, after fenestration of the floor of the third ventricle, we tried not to introduce the endoscope further. When we did need to introduce the endoscope, we made sure that visibility was completely clear and not obscured by blood. None of the procedures were abandoned due to bleeding, but external ventricular drains were placed in 13 patients. In subsequent cases with hemorrhage, we waited until the vision cleared to proceed. It is advisable not to proceed even when vision is mildly obscured.

During episodes of bleeding, we initially used irrigation. The majority of bleeding stopped spontaneously, but some episodes of bleeding were not easily controlled. Cortical bleeding trickling down into the ventricle was controlled using cotton patties around the endoscope over the cortical surface. Bleeding within the ventricles, caused by accidental tearing due to direct friction from the endoscope or unusual stretching of the veins, was controlled using continuous irrigation.

Sometimes bleeding was stopped using gentle pressure from the endoscope itself, directly over the site of hemorrhage. To avoid bleeding just after fenestration of the floor of the third ventricle, we selected an avascular area for fenestration. Fenestration was performed using blunt forceps, and when bleeding did occur, we inserted the balloon of the Fogarty catheter and inflated this with 0.3–0.4 ml of water and applied sustained pressure for 4–5 minutes (Fig. 1E). This procedure was usually sufficient to stop this bleeding. Long-sheathed monopolar cautery can also be used for fenestration, but we rarely used this technique. When severe bleeding occurred an external ventricular drain was left in situ following the ETV.

When there were large episodes of bleeding resulting in clot formation within the ventricle, irrigation was used to wash away the clot and prevent clogging of the cerebral aqueduct. When the clot could not be removed with irrigation, the balloon end of a Fogarty catheter was cut and the cut end was inserted through 1 working port and placed over the clot. A 3-ml syringe was attached to the other end of the catheter and sustained gentle suction was used to remove the clot along with the catheter through the working port. Large clots required repetition of this procedure. The basilar artery and its branches can easily be seen (Fig. 1F) after fenestration of the membrane. Therefore, it is not prudent to proceed until vision is clear.

CSF leakage occurred in 11 cases. In the immediate postoperative period, 5 patients had electrolyte imbalances (2 with hyperkalemia and 3 with hypernatremia). Two patients had convulsions and 1 patient had evidence of a third cranial nerve injury. Death related to the observed perioperative complications occurred in 3 patients.

In some patients ventricular anatomy was altered due to developmental anomalies, and the transparent membrane in front of the mammillary bodies was difficult to identify. In these cases, the whole of the third ventricle floor was inspected carefully and the most transparent part of the membrane was identified. When it was clear that no blood vessels or vital structures lay beneath the membrane, a small fenestration was performed with the blunt forceps. We did not use ultrasonography, but instead depended on the endoscopic view. Fortunately, we did not have to abandon any case without performing fenestration of the floor of the third ventricle.

**Treatment Outcome**

ETV was considered a failure when a further procedure was needed to treat the hydrocephalus. In this series, 32 patients were lost to follow-up at 6 months. In those patients who completed follow-up of at least 6 months, 298 (78.42%) of 380 were well after ETV. The outcome was good in most of the cases of aqueductal stenosis, but it was not great in children under 6 months of age. ETV was very successful in treating other conditions, such as posterior fossa tumor/cysts, posterior fossa hemorrhages, and congenital fourth ventricular outlet obstructions. ETV for Chiari malformations was successful in 4 cases, but 2 of 6 needed posterior fossa decompression. More than half of the cases of ventriculitis did well after ETV. These outcomes will be described in detail in a future publication.

**Discussion**

ETV is the most common neuroendoscopic procedure, with a reported success rate of 60%–90%. Due to the unique surgical maneuvers involved in ETV, it is sometime associated with serious complications that are difficult to manage. Intraoperative management is directed toward providing optimal conditions for surgery and preventing technical complications. One must ensure strict patient immobility during endoscopy and yet have a reasonably awake patient at the end of anesthesia to facilitate early neurological assessment. Serious intraoperative complications during neuroendoscopy can be caused by any of the surgical maneuvers involved, such as endoscopic manipulations inside the cavity, continuous irrigation with electrolyte solution, and perforation of the third ventricle floor.

Hemodynamic disturbances in the form of heart rate and blood pressure changes are the most frequently reported complications, with an incidence of 28%–32%. The cardiovascular response may be due to an acute rise in intracranial pressure (ICP) caused by continuous use of high-speed irrigation or obstruction to the outflow of fluid, leading to impairment of cerebral perfusion. Tachycardia and hypertension have been shown to correlate well with an acutely raised ICP during ETV. Inadvertent stimulation or injury of the posterior hypothalamus (which regulates the cardiac regulatory function of the brainstem via descending autonomic pathways) or of the third cranial nerves, both of which lie in close proximity to the endoscope, can lead to tachycardia and hypertension. Careful manipulation of the endoscope and avoidance of vigorous irrigation can help to minimize these complications. It is important to keep the endoscope as still as possible during irrigation to minimize the risk of bleeding. Additionally, the use of monopolar cautery can be helpful in controlling bleeding.

In summary, ETV is a valuable procedure for treating hydrocephalus, but it is not without risks. Careful patient selection, proper surgical technique, and appropriate intraoperative management are crucial to minimize complications and achieve successful outcomes.
to the third ventricle floor, can also produce significant hemodynamic responses. Bradycardia was reported in 43% and 41% of the patients in two separate studies during fenestration of the third ventricle floor, and in 26.8% of the patients during balloon inflation of a Fogarty catheter.

Rapid CSF drainage upon insertion of the endoscope may lead to sudden brain shifts with hemodynamic alterations. Use of saline for irrigation is also known to produce hypertension with reflex bradycardia, which may be confused with raised ICP. Hartmann’s solution is preferred as it does not cause hypertension and its ionic composition is closer to that of CSF. Most often, the observed heart rate and blood pressure changes are transient and respond to simple surgical maneuvers, but failure to recognize them in time can lead to serious consequences.

Prompt management of cardiovascular complications can be achieved by anticipation of the hemodynamic change specific to a surgical maneuver, necessitating close observation of surgery on the video monitor and, by early detection, requiring beat-to-beat monitoring of changes with an indwelling arterial catheter. Increases in ICP can be detected by directly measuring the ICP or the intraventricular pressures, although these may sometimes be unreliable. At our institute, we do not measure the ICP routinely and rely only on hemodynamic changes to alert the surgeons.

Minor hemorrhages are commonly encountered and are easy to control, whereas major bleeding can result in serious postoperative neurological sequelae. Injury to the basilar artery or basilar perforating vessels remains the most dangerous complication of neuroendoscopy and is associated with high morbidity and mortality. This potential for a basilar artery injury highlights the importance of a correctly placed fenestration on the third ventricle floor. Minor bleeding can occur from injury to the cortical vessels, septal veins, thalamostriate veins, veins from the ventricular floor, or other minor veins. During episodes of bleeding that obscure the vision of the endoscopes, we tried several maneuvers. Monitoring the color and volume of the returning perfusate is useful for assessing the extent of bleeding. In many cases, simple watchful waiting solved the issue of minor bleeding in this series.

Delayed awakening after neuroendoscopy has been reported in as many as 15% of patients, attributed largely to high pressure levels inside the neuroendoscope. Intraoperative air entrainment leading to a pneumoventricle or pneumocephalus with serious postoperative sequelae has been reported, but did not occur in any of our cases. Complications arising from poor surgical technique or an inadvertent injury to vital brain areas may manifest in the immediate postoperative period. Transient episodes of loss of consciousness, neurological deficits (8%–38% incidence), confusion, memory loss, and impaired cognitive function have been reported. Convulsions may occur due to neuronal hyperemia, intraventricular bleeding, or an electrolyte imbalance. Transient hypothalamic dysfunction may lead to a syndrome of inappropriate secretion of antidiuretic hormone and diabetes insipidus with fluctuating serum electrolyte levels, mandating their close monitoring in the postoperative period. Hyperkalemia, hypokalemia, hypernatremia, and hyponatremia have all been reported. Meningeal irritation, headache, and high fever can occur due to an inflammatory response to irrigating fluids or to spilled colloid cyst contents causing chemical ventriculitis. Transient ocular divergence and anisocoria can occur from inadvertent stretching of the midbrain and resultant palsies of third or sixth cranial nerves during fenestration of the third ventricle floor.

Bilateral retinal hemorrhage due to steep increases in ICP has also been reported. Respiratory arrest in 2 patients and cardiopulmonary arrest in 1 patient due to acute subdural collection has also occurred, reinforcing the importance of close monitoring in the immediate postoperative period.

Improved perioperative outcome from neuroendoscopic procedures is largely dependent on efficient and effective handling of potential complications. This requires an understanding of the complications possible at each different surgical step, meticulous intraoperative monitoring, effective communication between the surgeon and the anesthetist, and close vigilance of the patient in the postoperative period.

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Author Contributions
Conception and design: Kawsar. Acquisition of data: all authors. Analysis and interpretation of data: Kawsar. Drafting the article: Kawsar. Critically revising the article: all authors. Reviewed submitted version of manuscript: Kawsar. Approved the final version of the manuscript on behalf of all authors: Kawsar. Study supervision: Haque.

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