

Endoscopic third ventriculostomy

Yad Ram Yadav, Vijay Parihar, Sonjjay Pande¹, Hemant Namdev, Moneet Agarwal

Departments of Neurosurgery and ¹Radio diagnosis, NSCB Medical College, Jabalpur, Madhya Pradesh, India

ABSTRACT

Endoscopic third ventriculostomy (ETV) is considered as a treatment of choice for obstructive hydrocephalus. It is indicated in hydrocephalus secondary to congenital aqueductal stenosis, posterior third ventricle tumor, cerebellar infarct, Dandy-Walker malformation, vein of Galen aneurism, syringomyelia with or without Chiari malformation type I, intraventricular hematoma, post infective, normal pressure hydrocephalus, myelomeningocele, multiloculated hydrocephalus, encephalocele, posterior fossa tumor and craniosynostosis. It is also indicated in block shunt or slit ventricle syndrome. Proper Pre-operative imaging for detailed assessment of the posterior communicating arteries distance from mid line, presence or absence of Liliequist membrane or other membranes, located in the prepontine cistern is useful. Measurement of lumbar elastance and resistance can predict patency of cranial subarachnoid space and complex hydrocephalus, which decides an ultimate outcome. Water jet dissection is an effective technique of ETV in thick floor. Ultrasonic contact probe can be useful in selected patients. Intra-operative ventriculo-stomography could help in confirming the adequacy of endoscopic procedure, thereby facilitating the need for shunt. Intraoperative observations of the patent aqueduct and prepontine cistern scarring are predictors of the risk of ETV failure. Such patients may be considered for shunt surgery. Magnetic resonance ventriculography and cine phase contrast magnetic resonance imaging are effective in assessing subarachnoid space and stoma patency after ETV. Proper case selection, post-operative care including monitoring of ICP and need for external ventricular drain, repeated lumbar puncture and CSF drainage, Ommaya reservoir in selected patients could help to increase success rate and reduce complications. Most of the complications develop in an early post-operative, but fatal complications can develop late which indicate an importance of long term follow up.

Key words: Cerebrospinal fluid shunt, endoscopy, endoscopic third ventriculostomy, hydrocephalus, neuroendoscopy, ventriculostomy

Introduction

Endoscopic techniques are being increasingly used in the management of various neurosurgical pathologies, in recent times.^[1-4] Endoscopic third ventriculostomy (ETV) is well accepted for obstructive hydrocephalus of various etiologies.^[5-10] Success rate of ETV is poor in post-hemorrhagic, post-infective hydrocephalus. It is safe in properly selected cases. Good pre-operative planning, proper imaging, surgeons experience and good post-operative care help in improving results.

History of ETV

Ventriculostomy was introduced in the early 1900s. Walter E. Dandy used a primitive endoscope to perform choroid plexectomy in communicating hydrocephalus. He later introduced the sub-frontal approach for an open third ventriculostomy. The high mortality rate of this approach prompted Dandy to adopt a different treatment. Endoscopic management of hydrocephalus was attempted in 1910 when VLL'Espinasse, an urologist, used the cystoscope to cauterize the choroid plexus.

The first ETV was performed by William Mixter, an urologist, in 1923. He used a urethroscope to perform the third ventriculostomy in a child with obstructive hydrocephalus. Tracy J. Putnam made the necessary modifications in this urethroscope for cauterization of the choroid plexus. An advent of valve-regulated shunt systems and the simplicity of the shunt technique resulted in minimal advances in third ventriculostomies for next 30 years. In 1947, H. F. McNickle introduced a percutaneous

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Address for correspondence:

Dr. Yad Ram Yadav, 105 Nehru Nagar, Opposite Medical College, Jabalpur – 482 003, Madhya Pradesh, India.

E-mail: yadavyr@yahoo.co.in

method of performing third ventriculostomy that decreased the complication rate and improved the success rate. In the early 1970s, the leukotome was introduced to enlarge the perforation in third ventricle floor without an injury to the surrounding vascular structures. This percutaneous technique was further modified after the advent of stereotactic frames. This resulted in renewed interest in the use of ETV for the treatment of obstructive hydrocephalus. This was further supported by an advent of advanced fiber optic and lens technology. We now have small neuroendoscopes with deflectable tips, working ports, and good optic resolution, in addition to the rigid endoscopes with their excellent optic resolution. High definition camera has further improved visualizing and recording.

An improvement in the success of third ventriculostomy in recent time could be due to better patient selection; improvements in endoscope, better imaging, advanced surgical technique and instruments.

Indications of ETV

Endoscopic third ventriculostomy is increasingly used in the treatment of hydrocephalus. It is considered treatment of choice in obstructive hydrocephalus. It is also now advocated in some communicating hydrocephalus, such as normal pressure hydrocephalus by some authors. It is indicated in patients who demonstrate symptoms and signs of hydrocephalus and anatomical features amenable to a successful procedure. There should be an adequate space between the basilar artery and the clivus under the floor of the third ventricle to allow for a safe ventriculostomy.

Hydrocephalus could be of 3 types. Although ETV is indicated in selected patients in all types of hydrocephalus, the success of ETV in obstructive hydrocephalus is better than in communicating hydrocephalus.

Obstructive Type

Hydrocephalus, secondary to congenital aqueductal stenosis, posterior third ventricle tumor, cerebello-pontine angle tumor, other posterior fossa tumor are of obstructive variety. Hydrocephalus following cerebellar infarct, Dandy- Walker malformation, syringomyelia with or without Chiari malformation, shunt malfunction, encephalocele, craniosynostosis, intraventricular hematoma are usually of obstructive type. Myelomeningocele with hydrocephalus, slit ventricle syndrome and multiloculated hydrocephalus are also of obstructive hydrocephalus.

Communicating Type

Normal pressure hydrocephalus is of communicating variety. Some cases of hydrocephalus secondary to intraventricular hemorrhage, ventriculitis, meningitis and post-operative cases after complete excision of mass lesions are also of communicating variety.

Complex Hydrocephalus

Complex hydrocephalus is a variety of hydrocephalus when both the element of obstruction and the defect in the CSF absorption persist.^[11] Hydrocephalus after an infection and hemorrhage could be due to obstructive and communicating variety both. Hydrocephalus secondary to vein of Galen aneurism could be due to combination of obstruction and defect in CSF absorption. This explains comparatively poor results of ETV in hydrocephalus, following post-infective and post-hemorrhagic variety.

Hydrocephalus could be further classified into congenital, infectious, secondary to tumors and miscellaneous.

Congenital Etiology

Congenital aqueductal stenosis

Aqueductal stenosis is a common cause of obstructive (non-communicating) hydrocephalus. It could be due to congenital stenosis, acquired idiopathic, post-infectious or post-hemorrhagic and stenosis secondary to tumor. In congenital stenosis, aqueduct could be narrow or completely obstructed. Complete or near complete obstruction usually present in an early age while if obstruction is partial, the patients may be asymptomatic or present at a later age. Endoscopic third ventriculostomy instead of a shunt placement is considered better option for non-communicating hydrocephalus secondary to congenital aqueductal stenosis. Results of ETV are better in congenital hydrocephalus due to aqueductal stenosis as compared to post-hemorrhagic or post-infective hydrocephalus.^[5]

Dandy-Walker malformation

The Dandy-Walker syndrome (DWS) is associated with the posterior fossa enlargement, partial or complete agenesis of the cerebellar vermis, cystic dilation of the fourth ventricle. This often involves hydrocephalus and complications due to associated genetic conditions, such as spina bifida. Hydrocephalus can be treated by shunt surgery, but the ETV was found to be a preferential operative procedure.^[12] Endoscopic third ventriculostomy alone, ETV with aqueductal stent placement and ETV with fenestration of the occluding

membrane could be performed effectively and safely depending on existing pathology in DWS.^[13]

Vein of Galen aneurism and hydrocephalus

Aneurysms of the vein of Galen are uncommon vascular malformations and are frequently seen in infants and children, leading to heart failure and hydrocephalus. An obstruction of the cerebral aqueduct by an aneurism is one of the causes of hydrocephalus. Such hydrocephalus has been treated mainly with cerebrospinal shunt procedures. ETV has been found to be successful in huge hydrocephalus in vein of Galen aneurism.^[14]

Syringomyelia with or without Chiari malformation Type I

Chiari malformations refer to a spectrum of congenital hindbrain abnormalities affecting the cerebellum, brainstem, the upper cervical cord and the bony cranial base. Hydrocephalus occurs in 7% - 10% of patients with Chiari I malformation (CIM). Such patients can develop syringomyelia. Hydrocephalus and syringomyelia are commonly managed by shunt surgery. Syringomyelia and hydrocephalus with^[15] or without CIM^[16] can be successfully treated by ETV.

Encephalocele

Congenital hydrocephalus is commonly associated with encephalocele. Common varieties of encephalocele are occipital and sincipital. Hydrocephalus incidence is equally common among different encephalocele types. Endoscopic treatment by ETV or ETV with choroid plexuses coagulation was more successful (79%) than shunting (47%) at 1 year.^[17] Management of hydrocephalus and reducing the CSF pressure is crucial in preventing dehiscence at the site of the encephalocele repair.

Myelomeningocele with hydrocephalus

Hydrocephalus is quite common in myelomeningocele, especially in lumbar region. ETV can be used in the management of hydrocephalus associated with myelomeningocele. Narrow antero-posterior length of the third ventricular floor and narrow prepontine cistern are not infrequently observed in such cases, which may pose problems during ETV. Pre-operative evaluation and intra-operative inspection of these findings are very important in successful performance of ETV.^[18]

Craniosynostosis

Ventricular dilatation in the presence of primary craniosynostosis is a unique condition with respect to pathogenesis. It is rarely observed in non-syndromic craniosynostosis and in these cases, usually attributable to coincidental disorders. On the other hand, it is a common feature of syndromic craniosynostosis, affecting

at least 40% of patients with Crouzon's, Pfeiffer's or the Apert syndrome. Shunt-dependent hydrocephalus is predominantly associated with Crouzon or Pfeiffer syndrome while in the Apert syndrome, non-progressive ventriculomegaly is usually seen. The pathogenesis of progressive hydrocephalus remains somewhat obscure, a hypoplastic posterior fossa and a venous outlet occlusion at the skull base, being the main causative factors. Ventriculomegaly may reflect primary brain maldevelopment or in some cases, even a compensated state of increased CSF outflow resistance. The ventricular dilatation may become evident only after decompressive cranial surgery. Ventriculo-peritoneal shunting is the most common mode of treatment. Performing an ETV may facilitate control of hydrocephalus, associated with craniosynostosis in select cases. However, because of the relatively high failure rate of this procedure, a close clinical and radiological monitoring of these children is mandatory.^[19]

Post-infective etiology

Post infective hydrocephalus

Endoscopic third ventriculostomy, as an alternative to shunt procedures, is an established treatment for obstructive hydrocephalus in TBM.^[20-25] Endoscopic third ventriculostomy in TBM hydrocephalus could be technically very difficult, especially in acute stage of disease due to an inflamed, thick and opaque third ventricle floor.^[21,25] Results of ETV in TBM are better in good grade case.^[21,25] Poor results are observed in patients with cisternal exudates,^[23,25] thick and opaque third ventricle floor, acute phase,^[21,25] and malnourished cases, as compared to the patients without cisternal exudates, thin and transparent third ventricle floor, chronic phase, well-nourished cases. Due to poor results in an acute phase of tubercular meningitis, shunt insertion could be advised to start with, and the ETV is performed when shunt malfunction occurs. Clinical and radiological recovery could be very slow, especially in poor grade.^[24,25]

Hydrocephalus due to neurocysticercosis is usually associated with poor prognosis, and shunt failure is a common complication. An early extraction of parasite plus ETV may improve an outcome and reduce shunt failure.^[26,27] ETV and removal of the NCC was found to be better than shunt surgery.^[28]

Hydrocephalus secondary to tumor pathology

Biopsy of the posterior third ventricle tumor and ETV

Tumor of the posterior third ventricle with hydrocephalus could be managed by complete tumor excision, shunt surgery or external ventricular drainage, followed by tumor excision. Tissue diagnosis could be obtained in

83% - 100% cases.^[6,7] Endoscopic biopsy and ETV through a single or dual port was found to be safe and effective, and it avoids second surgery.^[8-10] Recurrent intracranial germinoma along the endoscopic ventriculostomy tract was described,^[29] however, Shono *et al*^[30] found it to be safe and claimed that the risk of tumor dissemination due to the neuroendoscopic procedures was minimal when the appropriate chemotherapy and radiotherapy were provided postoperatively. Computer-assisted planning and performing a navigated endoscopic procedure could help in performing both ETV and biopsy in a better way.^[31]

Posterior fossa tumor

Hydrocephalus associated with posterior fossa tumor could be managed by ventriculo-peritoneal shunt, tumor excision and ETV. We agree that the best option to treat hydrocephalus due to posterior fossa lesions is total excision. There are public hospitals where patient need to wait for a significant period for their definitive tumor surgery. ETV should be considered as an alternative procedure to VP shunt in controlling severe hydrocephalus, related to posterior fossa tumors while patients await their definite tumor excision. The use of pre-resectional ETV was found to be an effective and safe procedure with a high success rate.^[32] ETV was found to be better than VP shunt.^[33] However, ETV cannot always prevent post-operative hydrocephalus in all cases of posterior fossa tumor.^[34]

Most of the hydrocephalus's (about 87%) secondary to posterior fossa astrocytoma are cured after tumor resection alone on the other hand, there is low cure rate of hydrocephalus after tumor resection alone in medulloblastoma and ependymoma. Endoscopic third ventriculostomy is the best option in the treatment of persistent hydrocephalus after posterior cranial fossa tumor removal.^[35,36]

Trans-aqueductal removal of an intra-fourth ventricular cyst along with endoscopic third ventriculostomy with a rigid endoscope and angiographic curved tip catheter was found to be an effective treatment, which can obviate the need for posterior cranial fossa exploration. 30° scope help can be taken to better visualize aqueduct and 4th ventricle.^[28]

Cerebello-pontine angle tumor

Hydrocephalus associated with cerebello-pontine angle tumor could be managed by ventriculo-peritoneal shunt, tumor excision and ETV. Total excision of tumor is the best option. ETV is also an effective method of treatment of hydrocephalus in cerebello-pontine angle tumors.^[37]

Miscellaneous etiology

Shunt malfunction

Shunt malfunction is quite common, and some of them could have repeated malfunctions. Such patients with repeated block could be better managed by ETV. Formerly shunted patients have less favorable results, somewhat greater risk of serious complications; therefore, more experience is essential when offering them an ETV.^[38] Carefully selected patients with obstructive hydrocephalus could benefit from ETV after shunt malfunction, and about 70% become shunt free. On the other hand, looking to the poor results, Woodworth *et al*^[39] suggested that the ETV combined with concurrent CSF shunting may be an important strategy to prevent catastrophic treatment failure in obstructive hydrocephalus patients, with a history of multiple shunt revisions and complications.

Cerebellar infarct

Brainstem compression and obstructive hydrocephalus could be potentially fatal complication of cerebellar infarct, which could be managed by direct surgery or CSF diversion. Obstructive hydrocephalus associated with cerebellar infarction can also be effectively treated with endoscopic third ventriculostomy.^[40-42]

Intraventricular hematoma with obstructive hydrocephalus

Hydrocephalus is quite common after intraventricular hematoma and is associated with poor prognosis. An effective management of hydrocephalus could improve prognosis in this condition. An external ventricular drainage, thrombolysis do have limitations such as infections and re-bleeding. An evacuation of hematoma and ETV was found to be safe and effective.^[43,44] ETV improves prognosis by effectively managing the obstructive hydrocephalus,^[43] however, it may not prevent development of delayed communicating hydrocephalus, especially after delayed and incomplete hematoma removal.^[45]

Normal pressure hydrocephalus

Normal pressure hydrocephalus is of communicating variety. Ventriculo-peritoneal shunt and lumbar-peritoneal shunts are commonly practiced procedures in communicating hydrocephalus. Role of ETV in communicating hydrocephalus is controversial. ETV was found to be safe and effective in communicating hydrocephalus by various authors. They argue that the endoscopic third ventriculostomy is not an internal shunt alone but improve hydrodynamic in these cases. The intraoperative finding of mobility of the third ventricle floor after the ventriculostomy suggest that the ETV helps in the restoration of pulsatility of the ventricular walls.^[46,47] The criteria for identifying patients,

in whom ETV could provide control of hydrocephalus in communicating variety, are displacement of the third ventricle floor inferiorly into the interpeduncular cistern and displacement of the lamina terminalis anteriorly into the lamina terminalis cistern. Post-operative improvement in these displacements would correlate with the success of ETV.^[48-50]

Multiloculated hydrocephalus

Multiloculated hydrocephalus could develop after ventriculitis and intraventricular hemorrhage. This condition is difficult to treat, which may need multiple shunts and repeated revisions. Endoscope helps in breaking of the multiple loculations, which makes the multiloculated cavities into a single cavity. Shunt can be performed after communicating all the loculations. Endoscopy reduces shunt revision rate from 2.9 per year before fenestration to 0.2 per year after fenestration.^[51] ETV could be possible in 12.5% of cases in multiloculated hydrocephalus, and shunt insertion could be avoided.^[51]

Slit ventricle syndrome

The slit ventricle syndrome is defined as the triad in shunted patients of intermittent headaches, small ventricles, and a flushing reservoir that slowly refills. This condition is due to transient proximal catheter occlusion, and symptomatic patients typically respond to shunt revision that incorporates an anti siphon device or programmable shunts. The clinical improvement sometimes fails to occur or occurs only transiently after shunt. ETV can attain a symptom-free and shunt-independent state in these patients. A flexible neurofiberscope, with a small outer diameter could be inserted along the shunt tube into the collapsed ventricle and ETV, and shunt removal could be performed in some cases.^[52] Stereotactic guidance can be used to hit relatively small ventricle. Shunt can also be carefully blocked to allow ventricular dilation, and ETV could be performed in usual manner using rigid scope. Such patients could undergo distal shunt externalization and occlusion with ICP monitoring. Those patients demonstrating symptomatic hydrocephalus should undergo ETV and shunt removal. Patients with normal ICP should undergo shunts removal without ETV. Shunt can be removed without need of revision or ETV if patient does not complain of headache after 2 - 3 days of exteriorization and blockage of shunt when the ICP facility is not available. Although there is increased risk of ETV in slit ventricle syndrome,, there are reports of third ventriculostomy being used in these cases.^[52,53]

Pre-operative Imaging and Patient Selection

Pre-operative detailed knowledge of the posterior communicating artery distance from midline is

important to provide a safe lateral vascular border.^[54] 3D sequences with multiplanar reformat images may help to observe not only the Lilliequist's membrane but also other membranes, located in the prepontine cistern, which may be the reason of failed ETV.^[55,56]

A generous prepontine interval (PPI) is generally accepted as an anatomical feature that may affect the safety and functionality of ETV. Patients with an obliterated or reduced PPI can safely undergo ETV as surgeon gains sufficient experience in endoscopy.^[57,58] Cistern status is also an important determinant of outcome.

Complex hydrocephalus is very important cause of failure to improve after ETV.^[11] This is due to failure of CSF absorption, decreased or absence of patency of cranial subarachnoid space (SAS). Measurement of lumbar elastance and resistance can predict patency of cranial SAS.^[59]

Cerebrospinal fluid flow through the interpeduncular and prepontine cisterns is an important determinant in the success of ETV, which can be predicted by the ratio of early CSF stroke volume values of the interpeduncular and prepontine cisterns.^[60] Cine phase-contrast magnetic resonance imaging can be utilized as a method of distinguishing between communicating and non-communicating hydrocephalus and any abnormality in basal cisterns. Presence of good CSF flow in basal cistern does not guarantee successful outcome after ETV. *Xiao Di et al* found that phase contrast MRI cine flow in basal cistern failed to demonstrate significant differences between successful and failed ETV groups. This indicates that the distal CSF pathways beyond the basal cisterns, around the brain stem and cervicomedullary junction, may play an essential role in achieving ETV success in addition to an adequate fenestration.^[61]

Surgical Technique

ETV is performed in supine position with head flexed so that the burr hole site is at the highest point. This also avoids over drainage of CSF and an entry of air in the ventricles and subdural space, especially in large ventriculomegaly. Loss of CSF may also be a risk factor for post-operative subdural hematoma. Some authors even prefer semi-sitting position. It is important to note that the size of the lateral ventricles, foramen of Monro and third ventricle should be sufficiently large to allow an introduction of the endoscope and to navigate it into the third ventricle. Generally, the width of the third ventricle and foramen of Monro should be approximately 7 mm or greater. If a patient has slit ventricles, caused by over

shunting of CSF, it will first be necessary to externalize the shunt to control drainage until an adequate working diameter of the ventricles is achieved. Stereotactic guidance can be used as a surgical adjunct to access ventricle.

The optimal trajectory into the third ventricle through foramen of Monro and into the interpeduncular cistern is usually achieved with burr hole, placed at or just anterior to the coronal suture and about 2.5 cm – 3 cm lateral to the midline. Usually, right side burr hole is performed. An exact site of burr hole can be determined by a line, extending from interpeduncular cistern and foramen of Monro on to the skull. We use brain cannula to puncture ventricle and then introduce endoscope with sheath. Peel-away sheath with a diameter, just slightly larger than the endoscope, can be used. This enables an easy insertion of the endoscope into the ventricle without repeated trauma to cerebral cortex and ependymal vessels. It also allows for convenient egress of irrigation fluid, eliminating any risk of raised pressure. If any significant hemorrhage occurs in the ventricle as a result of the procedure, the peel-away sheath also facilitates copious irrigation until the hemorrhage is cleared. We use lactate solution irrigation through the endoscope under normal body temperature, using gravity as opposed to any pressure technique to avoid any barotraumas to the brain or ventricles.

Foramen of Monro can be identified by confluence of thalamo-striate vein, septal vein and choroid plexuses. Perforation in the third ventricle floor is made after negotiating endoscope through the foramen of Monro. Fenestration in the third ventricle floor should be in between mammillary bodies and infundibular recess, at the most transparent site. Location of basilar artery should be identified to avoid an injury and bleeding during procedure, and the fenestration should be made anterior to the artery complex. Microvascular Doppler probe inserted through the endoscope could be useful to locate artery if basilar artery is not seen. Position of *dorsum sellae* can be identified by gentle probing by the blunt instrument, such as bipolar forceps if the facility of Doppler is not available. Fenestration should be made just posterior to *dorsum sellae*. Water jet dissection technique can be used to prevent an injury to vessel and bleeding if the third ventricle floor is thick and opaque.^[62,63]

The third ventricular floor should be penetrated bluntly to avoid the risk of vascular injury. Although we avoid thermal or electric energy for this technique, laser assisted third ventriculostomy was found to be safe and effective by earlier authors.^[5] An initial fenestration is

then dilated up to approximately 5 mm or more opening by using French Fogarty catheter. In some cases, an imperforate membrane of Lilliequist can be identified, lying beneath the floor of the third ventricle. Such membrane, if present, should be opened under direct endoscopic visualization. An ultrasonic contact probe (NECUP-2) can be used to create minimal and controlled lesion in third ventriculostomy.^[64]

If any hemorrhaging is encountered during the procedure, copious warm fluid irrigation should be used until all bleeding is visibly stopped and the ventricular CSF is clear. We use careful intermittent closure of outflow channel to create tamponade effect. This helps in better visualization during bleeding. An external ventricular drain is kept if there was any oozing of blood. Some authors use reservoir routinely, which facilitates management and diagnosis if patients are suspected to have persistent elevation of ICP or block stoma. Ommaya reservoir in certain high-risk patients may be a useful option for achieving quick ventricular access by medical and non-medical personnel in case of deterioration after ETV.^[65-67] Any bleeding, from cortical surface if seen while the endoscope is removed, should be cauterized.

It is difficult, sometimes, to know patency of stoma and cistern after ETV per-operative, especially in hydrocephalus, following an infection and hemorrhage. An intra-operative evaluation of stomal and aqueductal CSF flow after ETV is important. ETV will fail if CSF flow across stoma or through the cistern is absent. Recently described intra-operative ventriculostomography (IOVSG) may provide valuable information by visualizing CSF flow in ventricular system. Radio-opaque contrast agent (iohexol 300 mg%) is injected into the third ventricle by a catheter, introduced through the working channel of the endoscope (total amount of 6 cc for adults and 3 cc for children). Mobile C-arm image intensifier system is used for qualitative evaluation of CSF flow across the stoma and in cisternal space. Intra-operative images in lateral plane are obtained in cine-mode at 6 frames per second.^[68] Pre-operative images are taken before procedure to look for the site of obstruction. Post-operative ventriculography is performed after advancing the catheter tip to the opening of stoma. Flow of contrast agent across the stoma and its disappearance from subarachnoid spaces is noted. Images are acquired at 1, 3 and 5 min to trace the radio opaque contrast. Functionality of stoma and subarachnoid space is assessed depending on rate of flow of contrast across the stoma. We have no experience of this technique, but Dr Mazhar Husain *et al* used this procedure and found it to be simple and safe technique that helps in confirming the

adequacy of endoscopic procedure during surgery, and thereby facilitating intra-operative decision about further management, such as the need for shunt.^[68] Functionality of stoma and subarachnoid space was assessed according to the following scale: Good – Rapid flow of contrast across the stoma with appearance of contrast in cisternal spaces. Rapid transit of contrast from cisternal spaces in less than 1 min was seen. Fair – Slow flow of contrast across the stoma with slow transit of contrast from cisternal spaces in 1 – 3 min. Poor – Poor flow of contrast across the stoma with retention of contrast in cisternal spaces for more than 3 min. ETV usually fails in poor group, and ventriculo peritoneal shunt is required.

Daljeet Singh *et al* also performed third ventriculography with 3 - 4 cc of omnipaque, injected through the side port of the endoscope in case of doubt of patency of the ETV stoma.^[69]

Grotenhuis perforator can be used in ETV, especially in transparent and thin floor. Some additional help is required in tough floor.^[70] Intra-operative observations of the patent aqueduct and prepontine cistern scarring are independent predictors of the risk of ETV failure. Such patients may be considered for shunt surgery peri-operatively.^[71] Endoscopic subfrontal approach to the lamina terminalis was carried out on 10 human cadaveric specimens through a mini craniotomy. The clinical potential use of this alternative third ventriculostomy was also pointed out by Spena *et al.*^[72]

Post-operative Imaging

A decrease in the ventricular size detected soon after endoscopic third ventriculostomy is associated with a satisfactory clinical outcome. This response continues during the first few months after surgery. The reduction is more prominent in acute forms of hydrocephalus. Reduction of the size of third ventricle width was more than the reduction in lateral ventricle size after successful ETV.^[73] MR ventriculography was effective in assessing subarachnoid space and stoma patency after ETV.^[50] Magnetic resonance imaging has provided considerable information regarding CSF dynamics. CSF flow could be qualitatively described as the flow-void sign that is best appreciated in areas of narrowing. The visualization of this effect on routine T1- weighted or T2-weighted MR images is not consistent. Sagittal T2-weighted turbo inversion-recovery MR images can detect flow-void sign better. If the stoma is very narrow, the sign may be very weak or even absent. MRI demonstration of the flow through the third ventricle floor seems to have no absolute predictive value as a flow void signal in that

region has also been observed in up to 50% of clinical failures.^[74] Cine phase contrast (PC) MR imaging could be useful even if no flow void is seen. Cine PC MR imaging has been increasingly used for evaluating cranial and spinal CSF flow. The phase contrast technique is sensitive, even to slow flow, and provides the potential for non-invasive flow quantification. Cine PC MRI may be used to determine the patency of the stoma and may be used in follow-up.^[75] Minor flow across the stoma appears to be an early sign of closure. The measurement of stroke volume in ventriculostomy using cine PC MRI provides functional information about the third ventriculostomy.^[76]

Success Rate of ETV and Age

There are controversies regarding the success of ETV in infants. Some authors found that the ETV success do not depend on an age of the patient.^[77,78] Others reported poor results, especially in neonates and in infants, younger than 2 months.^[79,80] Shim KW *et al*^[81] suggested that simultaneous endoscopic third ventriculostomy and ventriculo peritoneal shunt should be performed in infantile hydrocephalus due to poor results of ETV alone.

Kulkarni AV *et al*^[82] reported the relative higher risk of initial failure in ETV, than shunt in children. The relative risk becomes progressively lower for ETV after about 3 months. Patient could experience a long-term treatment survival advantage after an early high-risk period of ETV failure as compared to shunt. They observed that it might take several years, however, to realize this benefit.

Complications

Over all complication rate after ETV is about 2% - 15%, but the permanent complications are few. However, complications such as fever, bleeding, hemiparesis, gaze palsy, memory disorders, altered consciousness, diabetes insipidus, weight gain and precocious puberty are reported.

Intraoperative Complications

Intraoperative neural injury, such as thalamic, fornical, hypothalamic and midbrain injuries are also observed. Intraoperative bradycardia^[83] and hemorrhages including fatal hemorrhage due to basilar artery rupture are also reported. Attempts to perforate the ventricular floor can lead to bleeding, especially in hydrocephalus following an infection and hemorrhage.

Complication Avoidance

Forniceal injury and other neural injuries could be avoided by proper planning of burr hole, avoiding significant side movements and by selecting proper cases with significantly enlarged foramen of Monro and third ventricle. Per-operative bleeding should be avoided by using water jet dissection in thick and opaque third ventricle, avoiding significant stretching of structure, especially during perforation of tough third ventricle floor. Significant side movement should also be avoided to prevent bleeding due to an injury to structures, like fornix and veins at foramen of Monro. Rarely, blood might trickle from burr hole site into the ventricle; proper hemostasis must be achieved before entering the ventricle. Proper inspection is must before making perforation in the third ventricle floor; fenestration on the vessel must be avoided. Bradycardia due to raised ICP could be avoided by keeping outflow patent. Bradycardia due to stretching on the brain stem should be avoided, especially during perforation of tough third ventricle floor.

Early Complications

Central nervous system infections, fever, stoma block, CSF leak and post-operative intracranial hematomas were also seen. Post-operative mortality is also reported.^[84,85] Diabetes insipidus, weight gain, precocious puberty and abnormal prolactin levels were found after ETV. However, abnormal prolactin levels were not clinical significant in any of the studied patients.^[86] The study remained inconclusive whether ETV contributes to the abnormalities of prolactin levels or to other endocrine parameters in pediatric patients. They suggested the longitudinal studies to delineate the effect of ETV on endocrine regulation.

Chronic subdural hematoma or subdural hygroma can occur after ETV, especially after Omega reservoir.^[87,88] Rare complications like post-operative hyperkalemia, severe parkinsonism, acute respiratory alkalosis and tachypnea can occur after endoscopic third ventriculostomy.^[83,89-91]

Complication Avoidance

Post-operative fever could be due to use of electrocautery, which should be avoided. Post-operative CSF leak could be avoided by plugging cortical and dural opening by gel foam, direct dural closure, especially in large ventriculomegaly in infants,^[78] or by using artificial dural substitute and tissue sealant in at risk patients.

Post-operative CSF leak can also be reduced by galeal-pericranial flap.^[92] Subdural hematoma could be prevented by making burr hole at highest point by flexing the neck, proper hemostasis at burr hole site and by preventing brain collapse using constant fluid irrigation.

Delayed Complications

Most of the complications in the ETV patients occur within 4 weeks. However, delayed complications including stoma block can occur, and therefore, a longer follow-up is desirable. Delayed stoma block though very rare, can be fatal.^[93] Patients who undergo ETV for an infective hydrocephalus and Dandy-Walker malformation should receive long-term follow-up because late closure of the stoma may occur in these patients. Intraoperative observation of thickened arachnoid membranes at the level of the interpeduncular cisterns at the time of ETV and a progressive decrease in CSF flow through the stoma on cine MR imaging should be considered a significant risk of deterioration.^[75]

Post-operative care

ETV results are good in obstructive hydrocephalus. Post-operative failures usually occur early; regular clinical and radiological assessment must be performed, especially in the first years after the neuroendoscopic procedure.^[94]

Measurement of intracranial pressure during the immediate post-operative period after endoscopic third ventriculostomy could be required in patients who continue to have clinical features of raised ICP or failed to show an improvement after ETV.^[95,96]

Post-operative continuous ICP monitoring and external ventricular drain (EVD) insertions could be very useful in the ETV after shunt failure. This procedure could allow intermittent CSF drainage, could relieve symptoms of elevated ICP. It could also provide an accurate assessment of the success of the ETV and patency of the stoma in the early post-operative days using CT ventriculography. It can also be used to install antibiotics in cases of infection.^[97,98]

Some patients fail to show an improvement despite of patent stoma after ETV. This could be due to complex hydrocephalus (combination of obstructive and communicating).^[11] Lumbar puncture helps by increasing the compliance and the buffering capacities of the spinal subarachnoid spaces, it probably decreases the cerebrospinal fluid outflow resistance from the

ventricular system, facilitate the decrease in the ventricular volume and allowing faster permeation of CSF in the intracranial subarachnoid spaces. A cycle of 1 to 3 lumbar punctures should always be performed in patients who remain symptomatic after ETV, before ETV is assumed to have failed and an extra cranial cerebrospinal fluid shunt is implanted. Patients with temporary defect in CSF hydrodynamics would show clinical improvement after lumbar puncture while those with permanent defect in CSF absorption or permeation will need some form of shunt.^[99,100]

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