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ORIGINAL ARTICLE

Endoscopic Third Ventriculostomy: The Art of Driving

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Abstract

Background: **Ensuring effective endoscopic third ventriculostomy (ETV) based on sufficient scientific knowledge and wise decision-making will enhance the outcome.**

Methods: **A 3-year retrospective study including postoperative ETV cases of both sexes with obstructive hydrocephalus due to aqueductal stenosis/tumor with preoperative ETV-SS greater than or equal to 70, age greater than or equal to 6−600 months and follow-up for greater than or equal to 6 months with a postoperative radiological evaluation of the ETV-patency and cerebrospinal fluid dynamics.**

Results: **Among the 147 case series, 93 patients were included in this study. Patient demographics showed age distribution between infants, children, preadolescence, and adults were 83.8, 1.3, 2.7, and 12.2%, respectively. Aqueductal stenosis or tumor was 93.6 and 6.4%, respectively. All infants were presented with aqueductal stenosis. Whereas, a child (16.6%) and five adults (83.4%) presented with aqueductal tumors. The ETV success rate was 74%. We appreciated three types of Liliequist membrane (LM): thick/dense (33.3%), thin/transparent (63.3%), and fenestrated (3.4%). The failure was significantly attributed to inadequate communication with the basal cistern due to difficult/unsafe perforation of the thick/dense LM ($P = 0.001$), particularly in infants less than 12 months.**

Conclusion: **Proper candidate selection, adequate LM opening with reasonable visual confirmation of the basal cistern and appropriate follow-up will upsurge the ETV success rate. Clarifying specific nuances can lead to do fruitful ETV.**

Keywords: Cerebrospinal fluid, Endoscopic third ventriculostomy, Foramen of monro, Liliequist membrane

1. Introduction

Neurosurgeons should be aware that the adaptation period[1−6] following endoscopic third ventriculostomy (ETV) should not be mistakenly interpreted as failure. Besides, they have a duty to understand ETV as cerebrospinal fluid (CSF) diversion procedure. In good candidates,[7] ETV is an enjoyable neuroendoscopic voyage.[8,9] Feasibly, this 'Art of Driving' series will help young neurosurgeons (YNS) to do fruitful ETV.

The aim of the study: is to accentuate the indispensable triade for successful ETV: (i) Proper candidate selection, (ii) surgical guarantee of reasonable communication between the ventricular system and basal cisterns, and (iii) precise postoperative care.

2. Materials and methods

2.1. Study design, subject selection, duration and intervention

Consents from all patients/their parents who participated in this study, were obtained. This is a single surgeon 3-year retrospective study done between July, 2019 and June, 2022.

2.1.1. Inclusion criteria

Postoperative ETV cases of both sexes with obstructive hydrocephalus due to aqueductal

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stenosis/tumor with preoperative ETV success score (ETV-SS)[7] greater than or equal to 70, age greater than or equal to 6–600 months and follow-up for greater than or equal to 6 months with postoperative phase-contrast magnetic resonance images (PC-MRI) cerebrospinal fluid (CSF) flowmetry to evaluate the ETV-patency and ETV-CSF dynamics. All cases were operated with LOTTA ventriculoscopes using the 4K-HD camera. Fogarty arterial embolectomy catheters (FAEC) (code 12A0805F/120805F) size 5F (inflated balloon diameter of 11 mm) were used to enlarge the ETV stoma.

Radiological protocol and postoperative evaluation of ETV patency were determined by two investigators including an experienced independent radiologist, who was unknown to the patients' clinical data and the aim of the index study. Additionally, the data of overall flow and stroke volumes across the stoma is measured by the machine's own software. Based on these two points, the influence of bias on research results can be basically excluded.

2.1.2. Exclusion criteria

Patients with other etiologies, age less than 6 or greater than 600 months, previous shunt insertion, received augmenting procedures [choroid plexus coagulation (CPC)], done with another ventriculoscopes/cameras, without postoperative CSF flowmetry or missed during the follow-up were excluded from this study.

2.2. Statistical analysis

The collected data was tabulated, and SPSS 26.0 was employed for statistical analysis along with Microsoft Excel 2016 and MedCalC program software, version 19.1.3 (MedCalc Software Ltd, Ostend, Belgium). A value of $P < 0.05$ was considered significant.

2.3. Surgical technique and illustrative cases

Step 1. Setup and position: Supine ideal for endoscopy.

Step 2. Skin incision: Curved reservoir technique. The skin and periosteal flaps are opened separately, elevated in the opposite directions, and a subgaleal pocket is fashioned to accommodate CSF egress during the adaptation period.[1–6]

Step 3. Burr hole: It is tailored. Regularly mid-pupillary just anterior to coronal suture on the right side to get a direct line connecting the prepontine cistern, III-VT floor and calvarium using a rigid endoscopy.

Step 4. Cruciate Dural incision, and ventricular cannulation: CSF sample is obtained, before irrigation.

Step 5. Ergonomics: Three techniques for endoscopic handling were utilized; (I) dynamic holding the endoscope with left-hand and instruments with the right-hand (the assistant might asked to fix the endoscope at the burr hole to control the depth and to inflate the balloon), (II) assistant holds the endoscope to allow the surgeon to do dynamic bimanual technique and (III) fixation with multi-joint-endoscopic-holder.[8,9]

Step 5. Pertinent landmarks: Following identification of pertinent anatomical landmarks[8,9] around the foramen of Monro (FM) and navigating the third ventricle (Figs. 1 and 2) the tuber cinereum (TC), and mammillary bodies (MB) are evaluated (Fig. 2).

Step 6. ETV: Both TC and Liliequist membrane (LM) must be opened efficiently to achieve the ETV goal. Fenestration is done in the TC at the midpoint between the infundibulum and the MB (Figs. 3–5) with closed Decq forceps, then it is opened parallel to the clivus (in a way not to injure the basilar artery (BA)/brainstem/perforators) to enlarge the stoma (Fig. 2). This stoma is further dilated with FAEC.

Step 7. Visual confirmation of the basal cistern: (Figs. 2–5).

Step 7+. Tumor biopsy/debulking and hemostasis: This step is applied only for tumors or bleeding.[10] Following ETV, we redirected our focus posteriorly to the tumor within the cerebral aqueduct.

Step 8. Closure: Plug the burr hole with button-fashioned gelfoam. The wound is closed in layers.

3. Results

3.1. Patients' demographics (Table 1) (Fig. 6)

Among our 147 case series, 93 patients were included in this study. Our included candidates showed slight male predominance (57.3%). Age greater than or equal to 6–24 months (infants),

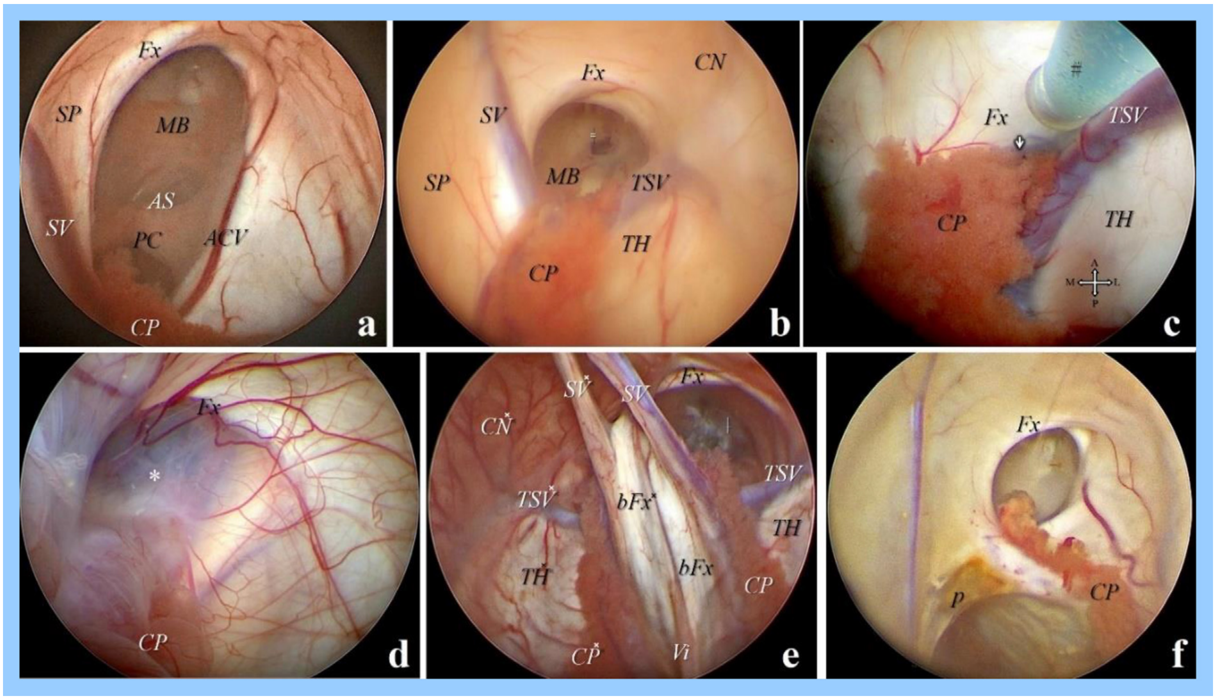

Fig. 1. Neuroendoscopic video-captured images from 6 different cases showing the endoscopic pertinent anatomical landmarks and types of foramen of Monro (FM). a) Huge FM can be seen from the (MB) mamillary bodies to the (PC) posterior commissure before navigating through the FM. (Fx) columns of Fornix, (SP) septum pellucidum, (SV) septal vein, (CP) choroid plexus, (ACV) anterior cudate vein, (AS) aqueduct of Sylvius. b) Wide FM where only part of III-VT floor includig the tuber cinerium (ǂ: ETV stoma site) and MB can be seen before navigating the FM. (CN) cudate nucleus, (TSV) thalamostriate vein, (TH) thalamus. c) Extremely narrow foramen of Monro (ENFM) white arrow. (#) Fogarty catheter. d) FM closed by a membrane (*). e) Wide FM with absent SP and everted velum interpositum (Vi) that allow an acess to both right and left structures. (SV^x) Left septal vein, (CN^x) left cudate nucleus, (TSV^x) left thalamostriate vein, (TH^x) left thalamus, (CP^x) left choroid plexus, (bFx^x) left and (bFx) right body of fornix. (f) FM without venous landmarks. Notice the pigmentations (P). (A) anterior, (P) posterior, (L) lateral, (M) medial.

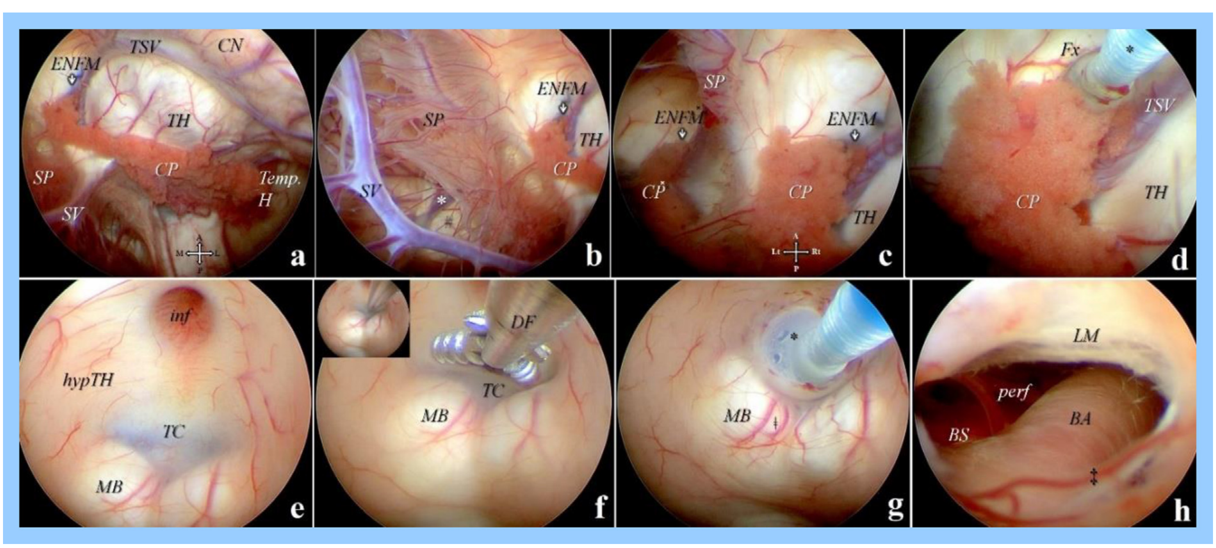

*Fig. 2. Neuroendoscopic video-captured images showing an ETV in Extremely narrow foramen of Monro (ENFM) (step-by-step). (a,b,c) initial exposure and orientation. (d) Dilating the ENFM with Fogarty arterial embolectomy catheters 'FAEC'(*). (e) III-VT floor landmarks. (f) ETV stoma creation with Decq forceps (DF) which is introduced closed (inset) then opened parallel to the clivus not to injure the hidden neurovascular structures. g) Enlarging the stoma with FAEC (black *). Notice the venules became engorged during balloon inflation (ǂ). h) Following Reasonable fenestration of the Liliequist membrane (LM) and visual confirmation of the basal cistern showing the brainstem (BS), basilar artery (BA) and its perforators and major branches (perf). (CN) cudate nucleus (TSV) thalamostriate vein, (TH) thalamus, (Temp H) temporl horrn, (CP) choroid plexus (SV) septal vein, (SP) septum pellucidum, ENFM (white arrow), contralateral TSV, (Fx) columns of Fornix,(inf) infundibular recess, (TC) tuber cinerium, (hypTH) hypothalamus, (MB) mamillary bodies, (‡) TC vessels.*

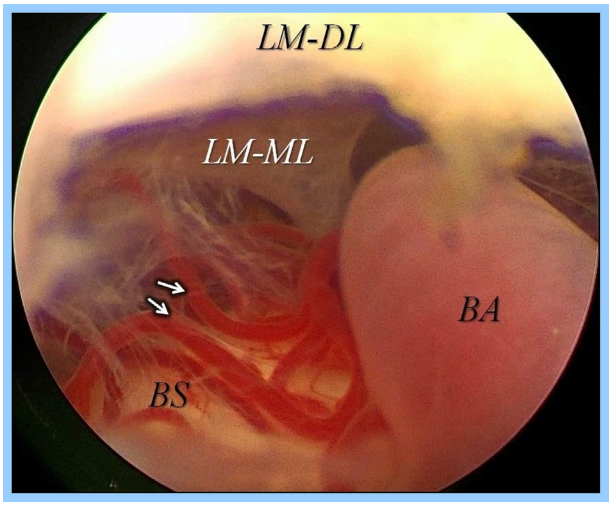

Fig. 3. Neuroendoscopic video-captured images showing examples of basilar artey (BA) exposure. The dense diencephalic layer of Liliequist membrane (LM-DL) have to be opened to see the brainstem (BS), basilar artery (BA) and its perforators (white arrows). The mesencephalic layer of LM (LM-ML) is fenestrated naturally in this case.

greater than 24–120 months (children), greater than 120–216 months (preadolescence), and greater than 216 to 600 months (adults) were 83.8, 1.3, 2.7, and 12.2%, respectively. Obstructive hydrocephalus due to aqueductal stenosis or tumor were 93.6 and 6.4%, respectively. All infants were presented with aqueductal stenosis. Whereas, a child (16.6%) and five adults (83.4%) were presented with aqueductal tumor. ETV with opening of LM and visual confirmation of the basal cisterns were achieved in all cases. Tumor biopsy was done in 5 cases (83.4%) and one adult consented only for ETV without biopsy from the midbrain/aqeductal tumor. The histopathology of biopsied cases revealed, germinoma, subependymoma, astrocytoma, in 20%, 40%, 40%, respectively.

The ETV success rate was 74%. In the index study we realized three types of LM (Fig. 5): thick/dense (33.3%), thin/transparent (63.3%) and fenestrated (3.4%). The failure rate were significantly attributed

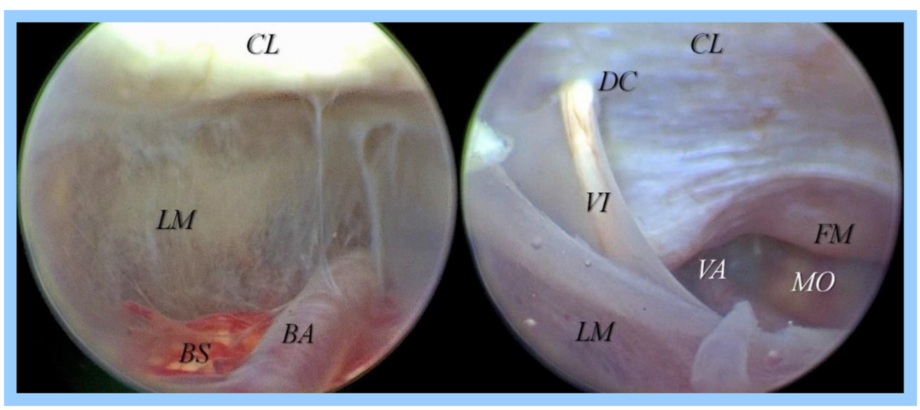

Fig. 4. Neuroendoscopic video-captured images showing the importance to open the Liliequist membrane (LM) as only naked basilar (BA) might not always enough. LM might prevent the CSF egress at the level of foramen magnum. Left) Following ETV, the basal cistern was found closed distally with intact LM. Basilar artery (BA), brainstem (BS), and clivus (CL) are identified beyond the transparent LM. Right) Following reasonable distal opening of LM we can appreciate the left vertebral artery (VA), medulla oblongata (MO), foramen magnum (FM), left abducent nerve (VI) entering the Dorello's canal (DC) (= resonable visual confirmation of the basal cistern).

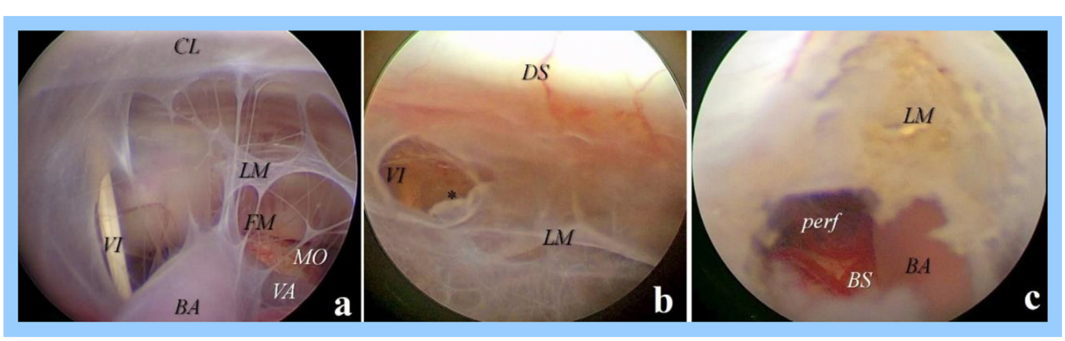

Fig. 5. Neuroendoscopic video-captured images from 3 different cases showing types of Liliequist membrane (LM). a) Fenestrated LM (3.4%) where the clivus (CL), foramen magnum (FM), medulla oblongata (MO), left abducent nerve (VI) and vertebrobasilar junction 'basilar artery (BA) vertebral artery (VA), can be confirmed. b) Thin/transparent LM (63.3%) extending from the dorsum sellae (DS) to cover the whole basal cistern. Notice our initial ETV stoma (*) exposing the left (VI). c) Thick/dense LM (33.3%). Notice our ETV stoma exposing the (BA) and its perforators (perf) in front of the brainstem (BS).

Table 1. Patients' demographics.

Case series	total number	147
	excluded	54
	included	93
Age (months)	≥6 to 24 (*infants*)	83.8%
	>24 to 120 (*children*)	1.3%
	>120 to 216 (*preadolescence*)	2.7%
	>216 to 600 (*adults*)	12.2%
Sex	male	57.3%
	female	42.7%
Etiology	aqueductal stenosis	93.6%
	aqueductal tumor	6.4%
Histopathology	germinoma	20%
	subependymoma	40%
	astrocytoma	40%
Types of LM	thick/dense	33.3%
	thin/transparent	63.3%
	fenestrated	3.4%
Outcome	ETV success rate	74%
	ETV failure rate	26%
Failure-related factors	difficult/unsafe perforation of the thick/dense LM ($P = 0.001$)	87.5%
	stoma closure with scar formation	4%
	delayed postmeningetic sequences	5.5%
	other	3%
Complications	unilateral trivial hurt 'red spots' to the column of the fornix	2%
	controllable bleeding due to minor venous injury around FM	4.4%
	subdural hygroma	–
	postoperative CSF leak	5.3%
	postmeningitic sequence	2%
	serious major neurovascular injuries	–
Subgaleal-CSF collection	soft (type I) without CSF leak	22%
	tense (type II) ± CSF leak	7%

to inadequate communication with the basal cistern due to difficult/unsafe perforation of the thick/dense LM (87.5%) ($P = 0.001$) particularly in infants less than 12 months, stoma closure with scar formation (4%), delayed postmeningetic sequences (5.5%) or other (3%).

We defined ETV success as resolution of symptoms with patent stoma on the postoperative CSF flowmetry and uneventful 6-month follow-up. While ETV failure was defined as persistent symptoms (including progressive head enlargement) that are resistant to postoperative CSF release (adaptation failure) with obstructed stoma on the postoperative CSF flowmetry during 6-month follow-up.

Complications: All intraoperative drawbacks were referred to inadvertent harms around the FM including unilateral trivial hurt 'red spots' to the column of the fornix (2%) which was attributed to the torque effect of the rigid endoscope around the FM during tumor biopsy or ETV via an extremely narrow FM[8] (Fig. 1c and 2). Controllable bleeding due to minor injury to venous structures (4.4%). Those cases had uneventful postoperative course.

No postoperative subdural hygroma. No serious major neurovascular injuries (intact vertebrobasilar arteries, perforators, major veins, cranial nerves, brainstem, mammillary bodies, optic apparatus, infundibulum, (hypo) thalamus, and basal ganglia).

Subgaleal (SG)-CSF collection/leak: tense SG collection (type II) was seen in 7% of cases, mostly less than 1 year. Among them, 5.3% showed at least on attack of CSF leak during the early adaptation-period which was controlled with the conservative measures. Two of them developed postmeningitic sequences (2%) with delayed ETV failure and required shunt. However, the soft SG collections (type I) in 22% were resolved spontaneously. In those cases (except 2% postmeningitic sequel), follow-up CSF flowmetry revealed good flow across the stoma.

4. Discussion

ETV is an effective cure for hydrocephalus and its success rate diverges according to the etiology (lower in infection, neural tube defects), age (lower <12 months), augmentation procedures[11–25] and accurate postoperative care.[8,9]

In our study we selected good candidates based on preoperative estimated ETV-SS Kulkarni and colleagues[7] greater than or equal to 70 with promising

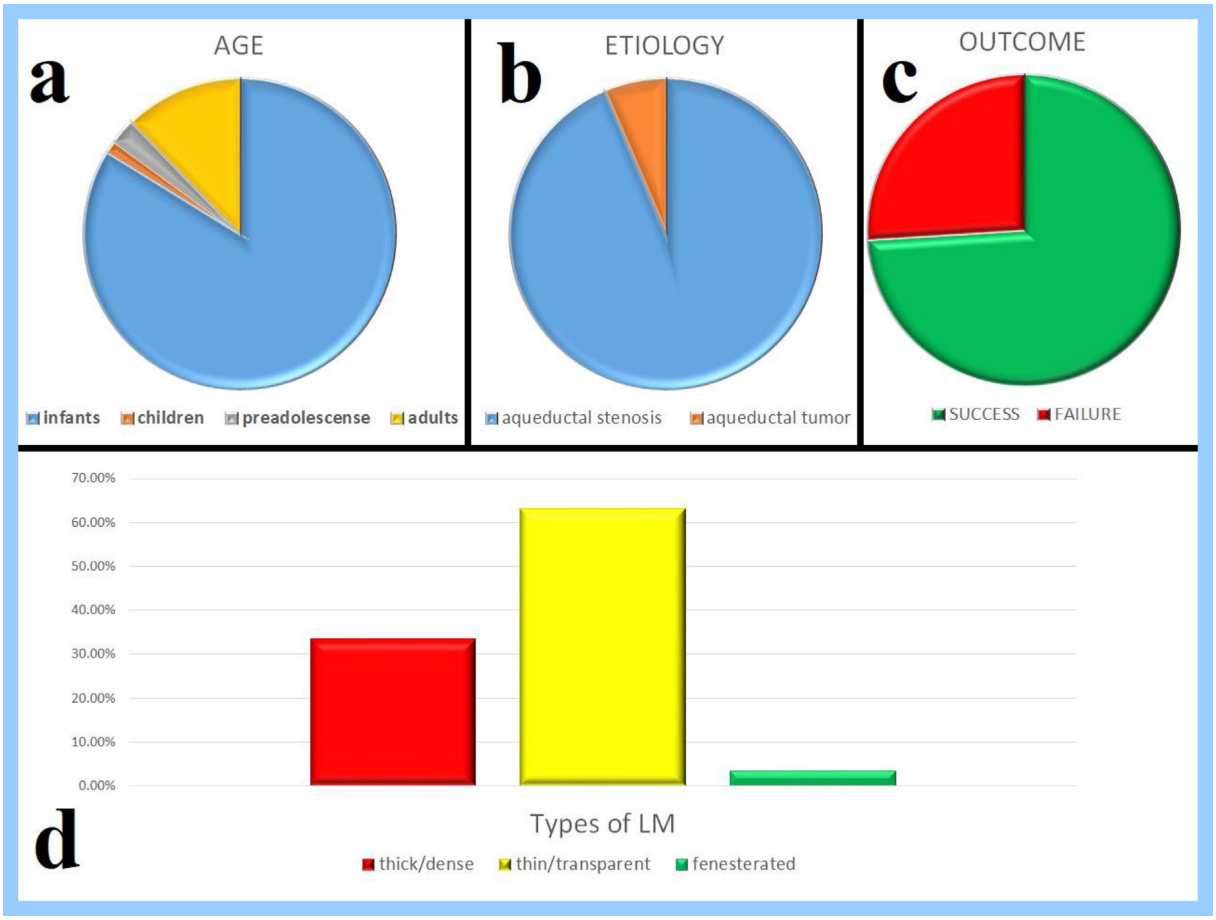

Fig. 6. (a,b) Patients' demographics and (c,d) Results.

age and definite etiology. Together with adequate opening of the LM, appropriate visual confirmation as mentioned by (Nagm and colleagues)[8,9] of the basal cisterns, proper postoperative management during the adaption period and radiological stoma assessment we reached a 74% success rate. Our outcome could be linked to the preoperative estimated ETV-SS.

4.1. Role of LM (Figs. 4 and 5)

LM opening must be performed to ensure adequate communication between the ventricular system and the subarachnoid space as mentioned by (Anik et al., and Mortazavi et al.).[21,25] Neurosurgeons should be aware of the LM types as declared by (Nagm et al., Anik et al., and Mortazavi et al.).[21–25] the difficulty level (thick/dense type) (Fig. 5c) and its impact on long-term ETV effectiveness. The higher the difficulty level to open the thick/dense LM, the significant the correlation with ETV failure ($P = 0.001$).

4.2. Role of PC-MRI CSF flowmetry

It is considered more reliable for evaluating the patency of ETV, and assessing ETV-CSF dynamics.[26–32] Higher stroke volumes (adequate flow = Grade III) at the ETV-stoma is a positive predictor of favorable clinical outcome. Consequently, in patients with low/impaired flow (Grade II/I) further careful observation is paramount as they might progress to occlusion.[9,26–32]

4.3. Role of curved reservoir skin incision with subgaleal pocket technique

During ETV-initial-postoperative adaptation-period, a voluminous quantity of CSF directly streams into the blocked basal cisterns leading to a recurrent increased intracranial pressure which is liable to be viewed as a failure.[11–20]

CSF release recover the compliance and buffering capacity of the basal cisterns, and optimize surgical outcomes.[11–25]

We have taken the advantage of our curved reservoir skin incision with subgaleal pocket technique to accommodate released CSF during the early adaptation period. This idea allows the CSF to egress via an opposite brilliant way (to be absorbed in the subgaleal pocket) to avoid unlikely acute obstruction. It allows the natural intermittent controlled CSF release/absorption according to the patient's own need.

5. Conclusions

This study fulfills the knowledge gap of previous literature that predicted ETV success only in pediatrics based on preoperative evaluation, and those included subjective intraoperative limited factors without radiological considerations or surgical pearls. The triade of proper candidate selection, surgical pearls to ensure rich communication between the third ventricle and basal cisterns, and appropriate postoperative management can change the game. Our advisory hints for neurosurgeons can lead them to ensure worthwhile ETV.

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No funds.

Authorship

The idea, design, acquisition/interpretation of data, operative photos, drafting and critical revising were done by the corresponding author (AN).

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Conflicts of interest

No.

References

1. Bellotti A, Rapanà A, Iaccarino C, Schonauer M. Intracranial pressure monitoring after endoscopic third ventriculostomy: an effective method to manage the ‘adaptation period’. *Clin Neurol Neurosurg*. 2001;103:223–227.
2. Rapanà A, Bellotti A, Iaccarino C, Pascale M, Schönauer M. Intracranial pressure patterns after endoscopic third ventriculostomy. Preliminary experience. *Acta Neurochir*. 2004; 146:1309–1315. discussion 1315.
3. Milhorat TH, Hammock MK, Di Chiro G. The subarachnoid space in congenital obstructive hydrocephalus. 1. Cisternographic findings. *J Neurosurg*. 1971;35:1–6.
4. Cinalli G, Spennato P, Ruggiero C, et al. Intracranial pressure monitoring and lumbar puncture after endoscopic third ventriculostomy in children. *Neurosurgery*. 2006;58:126–136. discussion 126–136.
5. Hu Z, Kang Z, Zhu G, et al. Experience with lumbar puncture following endoscopic third ventriculostomy for obstructive hydrocephalus. *J Neurol Surg Cent Eur Neurosurg*. 2017;78: 132–136.
6. Lenfeldt N, Koskinen LO, Bergenheim AT, Malm J, Eklund A. CSF pressure assessed by lumbar puncture agrees with intracranial pressure. *Neurology*. 2007;68:155–158.
7. Kulkarni AV, Drake JM, Mallucci CL, Sgouros S, Roth J, Constantini S. Canadian Pediatric Neurosurgery Study Group. Endoscopic third ventriculostomy in the treatment of childhood hydrocephalus. *J Pediatr*. 2009;155:254–259.
8. Nagm A, Ogiwara T, Goto T, Chiba A, Hongo K. Neuroendoscopy via an extremely narrow foramen of Monro: a case report. *NMC Case Rep J*. 2016;4:37–42.
9. Nagm A, Hemdan A, Salem A. Neuroendoscopic unrestricted Access to and visualization of the important anatomical structures at the third ventricle: surgical implications and image record. *AIMJ*. 2022;3:168–173.
10. Oertel J, Linsler S, Csokonay A, Schroeder HWS, Senger S. Management of severe intraoperative hemorrhage during intraventricular neuroendoscopic procedures: the dry field technique. *J Neurosurg*. 2018;131:931–935.
11. Cinalli G, Sainte-Rose C, Chumas P, et al. Failure of third ventriculostomy in the treatment of aqueductal stenosis in children. *J Neurosurg*. 1999;90:448–454.
12. Deopujari CE, Karmarkar VS, Shaikh ST. Endoscopic third ventriculostomy: success and failure. *J Korean Neurosurg Soc*. 2017;60:306–314.
13. Dewan MC, Naftel RP. The global rise of endoscopic third ventriculostomy with choroid plexus cauterization in pediatric hydrocephalus. *Pediatr Neurosurg*. 2017;52:401–408.
14. Fallah A, Weil AG, Juraschka K, et al. The importance of extent of choroid plexus cauterization in addition to endoscopic third ventriculostomy for infantile hydrocephalus: a retrospective North American observational study using propensity score-adjusted analysis. *J Neurosurg Pediatr*. 2017; 20:503–510.
15. Jaeger M, Khoo AK, Conforti DA, Cuganesan R. Relationship between intracranial pressure and phase contrast cine MRI derived measures of intracranial pulsations in idiopathic normal pressure hydrocephalus. *J Clin Neurosci*. 2016;30: 169–172.
16. Kulkarni AV, Riva-Cambrin J, Rozzelle CJ, et al. Endoscopic third ventriculostomy and choroid plexus cauterization in infant hydrocephalus: a prospective study by the Hydrocephalus Clinical Research Network. *J Neurosurg Pediatr*. 2018; 21:214–223.
17. Stone SS, Warf BC. Combined endoscopic third ventriculostomy and choroid plexus cauterization as primary treatment for infant hydrocephalus: a prospective North American series. *J Neurosurg Pediatr*. 2017;14:439–446.
18. Stovell MG, Zakaria R, Ellenbogen JR, et al. Long-term follow-up of endoscopic third ventriculostomy performed in the pediatric population. *J Neurosurg Pediatr*. 2016;17: 734–738.
19. Zandian A, Haffner M, Johnson J, Rozzelle CJ, Tubbs RS, Loukas M. Endoscopic third ventriculostomy with/without choroid plexus cauterization for hydrocephalus due to hemorrhage, infection, Dandy-Walker malformation, and neural tube defect: a meta-analysis. *Childs Nerv Syst*. 2014;30: 571–578.
20. Beems T, Grotenhuis JA. Long term complications and definition of failure of neuroendoscopic procedures. *Child's Nerv Syst*. 2004;20:868–877.
21. Anik I, Ceylan S, Koc K, et al. Microsurgical and endoscopic anatomy of Liliequist's membrane and the prepontine membranes: cadaveric study and clinical implications. *Acta Neurochir*. 2011;153:1701–1711.
22. da Costa Val Filho JA, da Silva Gusmão SN, Furtado LMF, de Macedo Machado Filho G, Maciel FLA. The role of the Liliequist membrane in the third ventriculostomy. *Neurosurg Rev*. 2021;44:3375–3385.

23. Dias DA, Castro FL, Yared JH, Lucas Júnior A, Ferreira Filho LA, Ferreira NF. Liliequist membrane: radiological evaluation, clinical and therapeutic implications. *Radiol Bras*. 2014;47:182–185.
24. Anõk I, Ceylan S, Koc K, Anõk Y, Etus V, Genc H. Membranous structures affecting the success of endoscopic third ventriculostomy in adult aqueductus sylvii stenosis. *Minim Invasive Neurosurg*. 2011;54:68–74.
25. Mortazavi MM, Rizq F, Harmon O, et al. Anatomical variations and neurosurgical significance of Liliequist's membrane. *Childs Nerv Syst*. 2015;31:15–28.
26. Alves T, Ibrahim ES, Martin BA, et al. Principles, techniques, and clinical applications of phasecontrast magnetic resonance cerebrospinal fluid imaging. *Neurographics*. 2017;7: 199–210.
27. Anik I, Etus V, Anik Y, Ceylan S. Role of interpeduncular and prepontine cistern cerebrospinal fluid flow measurements in prediction of endoscopic third ventriculostomy success in pediatric triventricular hydrocephalus. *Pediatr Neurosurg*. 2010; 46:344–350.
28. Bargalló N, Olondo L, Garcia AI, Capurro S, Caral L, Rumia J. Functional analysis of third ventriculostomy patency by quantification of CSF stroke volume by using cine phase-contrast MR imaging. *Am J Neuroradiol*. 2005;26:2514–2521.
29. Hassanien OA, Abo-Dewan KA, Mahrous OM, El Kheshin SE. Evaluation of the patency of endoscopic third ventriculostomy using phase contrast MRI-CSF flowmetry as diagnostic approach. *Egypt J Radiol Nucl Med*. 2018;49:701–710.
30. Oner Z, Sagir Kahraman A, Kose E, et al. Quantitative evaluation of normal aqueductal cerebrospinal fluid flow using phase contrast cine mri according to age and sex. *Anat Rec*. 2017;300:549–555.
31. Öztürk M, Sõğõrcõ A, Ünlü S. Evaluation of aqueductal cerebrospinal fluid flow dynamics with phase-contrast cine magnetic resonance imaging in normal pediatric cases. *Clin Imag*. 2016;40:1286–1290.
32. Lev S, Bhadelia RA, Estin D, Heilman CB, Wolpert SM. Functional analysis of third ventriculostomy patency with phase-contrast MRI velocity measurements. *Neuroradiology*. 1997;39:175–179.