The Role of the Liliequist Membrane in the Third Ventriculostomy

Jose Aloysio Costa Val Filho (✉ costaval.bh@terra.com.br)

Vila da Serra Hospital: Hospital Vila da Serra <https://orcid.org/0000-0003-3261-7147>

Sebastião Nataniel da Silva Gusmão

Department of Surgery, Faculty of Medicine and Department of Pediatric Neurosurgery of Hospital das Clínicas, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil

Leopoldo Mandic Ferreira Furtado

Department of Surgery, Faculty of Medicine and Department of Pediatric Neurosurgery of Hospital das Clínicas, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil

Guaracy de Macedo Machado Filho

Department of Neurosurgery, Federal University of Vales do Jequitinhonha e Mucuri, Diamantina, Minas Gerais, Brazil

Fernando Levi Alencar Maciel

Department of Neurosurgery, Federal University of Vales do Jequitinhonha e Mucuri, Diamantina, Minas Gerais, Brazil

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Abstract

Endoscopic third ventriculostomy (ETV) is a hydrocephalus treatment procedure that involves opening the Liliequist membrane (LM). However, LM anatomy has not been well-studied neuroendoscopically, because approach angles differ between descriptive and microsurgical anatomical explorations. Discrepancies in ETV efficacy, especially among children age 2 and younger, may be due to incomplete LM opening. The objective of this study was to characterize the LM anatomically from a neuroendoscopic perspective to better understand the impact of anatomical features during LM ostomy and the ETV success rate. Additionally, the ETV success score was tested to predict patient outcome after the intraoperatively difficult opening of LM. Fifty-four patients who underwent ETV were prospectively analyzed with a mean follow-up of 53.1 months (1–90 months). The ETV technical parameters of difficulty were validated by seven expert neurosurgeons. The pediatric population (44) of this study represents the majority of patients (81.4%). The overall ETV success rate was 68.5%. Anomalies on the IIIIVT floor resulted in an increased rate of ETV failure. The IIIIVT was anomalous, and LM was thick in 33.3% of cases. Fenestration of LM was difficult in 39% of cases, and the LM and TC were opened separately in 55.6% of cases. The endoscopic third ventriculostomy success score (ETVSS) accurately predicted the level of difficulty opening the LM ($p = 0.012$), and the group with easy opening presented greater durability in ETV success. Neurosurgeons should be aware of the difficulty level of the overture of LM during ETV and its impact on long-term ETV effectiveness.

Introduction

Endoscopic third ventriculostomy (ETV) is a procedure to treat hydrocephalus that allows ventricular cerebrospinal fluid to be diverted into the subarachnoid cisterns. Despite the efficacy of ETV, discrepancies have been reported in pediatric populations [1,3,4,13,25,26,40,42,46]. These discrepancies are likely caused by the non-observance of technical details.

To promote ventricular-subarachnoid cistern communication, a third ventricle (IIIIVT) floor must be opened at the tuber cinereum (TC). After opening the TC, an arachnoid membrane, the Liliequist membrane (LM), must be opened. The LM represents the superior limit of the interpeduncular cistern (IC) [1,8,18,22]. Sometimes the opening of LM is technically easy; TC and LM are juxtaposed, so as LM is thinned, the two structures can sometimes be opened simultaneously. Other times, these structures may be thick and opaque, or present anatomical variations. On such occasions, each structure must be opened separately, thus requiring two different maneuvers. Therefore, these procedures may be technically difficult, thus requiring specific knowledge of LM anatomy and its relationship with the TC [33].

Although cistern anatomy has been described, it is primarily based on descriptive cadaveric studies or microsurgical anatomy [5,32,2,38]. Little is known about anatomies from a neuroendoscopic perspective, as few descriptions are based on *in vivo* neuroendoscopic observations [14]. Different approach angles, diverse spatial orientations, and particularities associated with etiologies and age groups can lead to

inadequate LM recognition, which then causes failure in opening this structure [27]. Partial opening results in ineffective ETV [14].

To predict the success of ETV, Kulkarni et al [26] designed an assessment score based on preoperative variables, such as the patient's age, hydrocephalus etiology, and previous shunt placement, and reached an acceptable level of accuracy in predicting ETV success for the first six months postoperative, with appropriate reproducibility in various populations worldwide [19,15,34,6,29]. Furthermore, these authors considered a "naked basilar artery," which refers to exposure of the artery during ETV and the subsequent overtone of LM as an isolated intraoperative factor for success prediction [27].

To understand how the anatomical characteristics of LM and anomalies in the IIIVT floor could impact the difficulty level of the procedure and the prediction of long-term ETV efficacy, we standardized the definition of "difficulty" during this procedure and conducted a prospective study of a mixed-age population. As a secondary goal, we studied the predictability of endoscopic third ventriculostomy (ETVSS) to determine the ETV difficulty level.

Materials And Methods

Study population and eligibility criteria

This study was approved by the Federal University of Minas Gerais Ethics Committee (protocol #1.515.461). To provide a high level of evidence using observational studies, the STROBE guidelines were followed in this study.

Between July 2011 and February 2014, 54 patients were treated with ETV by the same neurosurgeon. Only patients undergoing first ETV were included, and their etiologies were categorized according to aqueductal stenosis, non-tectal brain tumors, tectal brain tumors, myelomeningocele, intraventricular hemorrhage, and/or postinfectious. All ages were deemed appropriate for this study. Patients with non-obstructive hydrocephalus, such as normal pressure hydrocephalus, were excluded from this study. All patients underwent magnetic resonance imaging (MRI) to assess the etiology of hydrocephalus.

Endoscopic technique

Patients were placed on a dorsal decubitus with their heads stabilized in a neutral position on a horseshoe-shaped headrest. A U-shaped skin surgical incision was made, and a burr hole was placed guided by imaging. If the anterior fontanelle remained open, an osteoplastic mini-craniotomy was performed [12]. Cortex perforation was performed with diathermy, using a rigid neuroendoscope (Aesculap or Karl Storz). Guided by the position of IIIVT floor landmarks, an entry point was made between the mammillary bodies and the infundibulum. The TC was punctured by bipolar diathermy or directly with an embolectomy catheter. The LM was located, verified, and opened in all cases. The stoma was enlarged by inflating a balloon to achieve adequate fenestration.

Assessment of intraoperative ETVs variables

We established intraoperative variables for evaluating the ETV based on the following criteria: endoscopic features of the anatomy of the IIIIVT floor, LM, difficulty performing the overture of these membranes, and whether these membranes opened together or separately.

The anatomy of the IIIIVT floor was considered to be conventional if the visualization included the infundibular recess anteriorly, mammillary bodies posteriorly, and hypothalamus laterally (Figure 1). We considered the IIIIVT floor to be an abnormality in the presence of tissue alterations such as scar or gelatinous consistency, signs of previous bleeding on the ependyma's surface, and anatomy distortion (Figure 2).

To better define the concept of difficulty in the "IIIIVT Floor opening technique" and "LM opening," a face validation approach was performed and several criteria were created based on the consultation of seven neuroendoscopy experts from Brazilian medical institutions who perform more than 30 ETV procedures each year (Table 1,2) (Videos 1,2).

After the procedure, data from a questionnaire filled out by the neurosurgeon, as well as data on any eventual intraoperative complication were recorded (Table 3).

ETV success criteria and follow-up

The neuroendoscopic procedure was considered effective if all symptoms of intracranial hypertension resolved. In a pediatric population aged two years and younger, head shape was normalized and fontanelle tension improved. Otherwise, the procedure was considered failed, which was determined by no clinical improvement and the need for conversion of a shunt device or a secondary ETV.

MRI parameters, such as Evan's index or the frontal occipital horn ratio, were not considered for this study. We deemed a clinical improvement as the only parameter for ETV success, even though most patients underwent a secondary brain image during follow-up to assess brain adaptation.

After hospital discharge, all patients were followed by the same neurosurgeon monthly for the first year and quarterly in subsequent years if clinical improvement required close surveillance if any symptoms were present.

Statistical methods and data analysis

Statistical analyses were performed using SPSS ver. 20 software (IBM, Armonk, NY, USA), Minitab 16 Statistical Software (Minitab, PA, USA), and Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA).

The ETVSS for each patient was obtained according to the rules of scoring proposed by Kulkarni's work [26]. To evaluate the accuracy in of this score in predicting intraoperative level of difficulty, we constructed a Receiving operating characteristic (ROC) curve.

Next, the two-proportion equality test (chi-squared test) was used to compare the levels of difficulty based on age and etiological covariates, and to assess whether intraoperative variables could be used to predict the ETV success during the first six months. The variables were considered based on the presence of abnormalities on the IIIVT floor (Yes/No), TC aspect (opaque/translucid), LM aspect (Thin/Thick), level of difficulty of the TC overture (Easy/Hard), level of difficulty of the LM opening (Easy/Hard), and whether the TC and LM opened together or separately.

To appreciate the long-term efficacy of ETV, we divided the patients into two groups according to the level of difficulty observed during ETV and the results of an analysis that assessed the durability of ETV success using the Kaplan-Meier curve.

Analysis of variance (ANOVA) was used to evaluate the variable medians. Student's *t*-test was performed to compare the LM and TC and their levels of difficulty. Differences were considered significant when $P < 0.005$.

Results

Study population

The majority of the population in this study included pediatric patients 44 (81.5%), and 20 (45.5%) were less than one year of age (Table 4). The mean duration of follow-up was 53.1 months, ranging from 1 month to 96 months.

In the pediatric population, aqueductal stenosis was the most common etiology, followed by myelomeningocele (Table 4). Among adults, the common etiologies were distributed between aqueduct stenosis diagnosed as longstanding overt ventriculomegaly in adults (LOVA), infection/parasite, and intracranial tumors. One adult died after one month of ETV due to pulmonary complications related to primary disease, which was intraventricular hemorrhage. No complications or fatalities were observed due to the ETV.

Intraoperative variables and the prediction of ETV success

The overall success rate of ETVs was 68.5%, and the relative distribution of the success rates according to ages is presented in Table 5. The success rate in patients with aqueductal stenosis was 75%.

Anomalies in the anatomy of IIIVT's floor were observed in one-third of patients and, because of the statistical significance, occurrence of anomalies was a unique intraoperative variable that could be used to predict the ETV success until six months after the procedure ($p = 0.038$). Whereas patients with regular anatomy presented 77% ETV success, a 50% failure rate was observed among patients with abnormalities on the IIIVT floor. Among patients with abnormalities on the IIIVT floor, half were due to anatomical distortions, with 38.9% caused by inflammation and 11.1% caused by hemorrhages. The majority of TCs were translucent in appearance, whereas opaque TCs were predominantly associated with anatomic distortions. However, in three patients with translucent TCs, anatomic abnormalities were

found. (Figures 1 and 2). Usually, opaque TCs were associated with thick LMs (67%, $p = 0.001$), which was correlated with difficulty opening the LM (61%, $p < 0.001$) (Figure 3). Difficulty opening the IIIVT floor was reflected in the difficulty of opening the LM. When the LM was thick (33%), it was more difficult to open ($p < 0.001$). When the LM was separated from the IIIVT floor (37%), opening was also difficult ($p < 0.001$).

The anatomic appearance of TC was not associated with ETV failure ($p = 0.136$). Similarly, other intraoperative variables showed no accuracy in predicting ETV success during the first six months of the procedure, and the p -values encountered were the LM thickness ($p = 0.407$), difficulty level of LM overture ($p = 0.102$), difficulty level of TC overture ($p = 0.151$), and whether the LM and TC opened in a separate fashion ($p = 0.394$).

Nevertheless, a difference in the durability of ETV success was observed 10 months after the procedure, according to the Kaplan–Meier curves (Figure 4) regarding intraoperative variables, such as the level of difficulty and LM/TC type of overture. Additionally, this difference was not statistically significant ($p > 0.005$). The majority of cases of ETV failure occurred during the first ten months after the procedure.

There was no statistical difference in the surgical duration between the groups of easy LM opening (mean = 49.7 minutes) and difficult LM opening (mean = 55.9 minutes) ($p = 0.336$); easy TC opening (mean = 49.6 minutes) or difficult TC opening (mean = 56.7 minutes) ($p = 0.290$); and whether the membranes opened together (mean = 52.9 minutes) or separately (mean = 51.9 minutes) ($p = 0.253$).

ETVSS and intraoperative variables

The significance of the predicted values of ETVSS and the level of difficulty of LM overture ($p = 0.012$) for the group that have an easy overture, the mean value of ETVSS were 60% probability of success, whereas the difficult overtures had 50% probability of success. Furthermore, by using the ROC curve to establish the accuracy of ETVSS in predicting the level of difficulty in opening the LM, an area under the curve of 0.698 was observed, and the cut point was 50% in a significant area under the curve (Figure 5).

In this population, the ETVSS matched the actual success rate, even after one year of the procedure, and for the group with low probability of success (ETVSS < 40), the failure rate was 83.3% (10 patients); for the group with moderate probability of success (50–70%), the success rate was 79% (20 patients); and for the group with high probability of success (> 80%), the actual success rate was 100% (15 patients).

Discussion

Liliequist membrane

The anatomical characteristics of the IIIVT and cisterns are well-known, and several descriptions exist, dating from the XVII century. Initially, these studies focused on descriptive anatomy, using fixed anatomical specimens. The earliest documented LM description was in 1875, by Key and Retzius, but the structure remained unelucidated for many years [11], until it was “rediscovered” in 1957 by Liliequist,

through pneumoencephalography observations in human cadavers [30]. Between the 1970s and 1990s, many studies of cisterns and the LM were performed, especially after Yasargil's work [50]. Several authors have described their anatomical findings, and numerous in-depth reports have been published [5,31,32,36,38,44,45]. However, most of these studies used the microscopic surgical approach [48,31,45,44].

In the 2000s, Inoue et al. [24] studied the ventricular system and cisterns, including angles viewed during neuroendoscopy. Since then, many other studies have examined the LM neuroendoscopically [1,14,37,38,48], which has clarified that the LM varies widely in morphology, behavior, and consistency. The wide range in characteristics of LMs leads to differences in what the ETV technique can achieve. However, despite this acquired knowledge, little progress has been made toward *in vivo* LM characterization to determine its relationship with the TC.

Impact of TC/LM anatomy on ETV

ETV requires opening the IIIVT floor at the TC epicenter. The TC is a thin layer of gray substance, which is associated with the ependyma, starting anteriorly from the infundibular recess to the mammillary body posteriorly and limited laterally by the hypothalamus. LM forms a band of arachnoid tissue and is inferior to TC, which originates from the posterior sella turcica and splits. In most cases, there are two portions, including an upper diencephalic leaf, which connects to the diencephalon along the posterior edge of mammillary bodies, and a lower mesencephalic leaf, which attaches along the midbrain junction and the pons. The space between the two leaves is the IC (44) (Figure 4). Generally, the mesencephalic leaf has an open border at its lower limit, which allows natural ICs to communicate with the pre-pontine cistern below it. (Figure 5). However, this border is naturally closed sometimes, so communication between cisterns does not always occur, or the LM may be absent [17].

ETV must facilitate communication between the IIIVT and IC through the surgical opening of the TC and LM (diencephalic portion). If this does not occur, communication will not complete and the surgery will be ineffective [1,8,16,22,26,33,41,49]. When the mesencephalic portion of the LM is not naturally continuous with the pre-pontine cistern, surgical opening of the mesencephalic part will be required [33].

ETV success and technical aspects of the TC/LM overture

Currently, ETV is widely performed [49,42,41,27,25,20,40,26,7,39]. However, discrepancies in its efficacy can be found throughout the literature [3,7,4,13,25,26,40,42,46]. The technical details of the ETV procedure may vary among providers, although incomplete opening of the TC or LM could also contributed to these discrepancies [22,43]. Misunderstanding the anatomy can lead to technical failure [14]. It remains unclear whether the LM has the same characteristics *in vivo* as those described during anatomical dissections and whether the TC/LM relationship *in vivo* differs from that described in previous anatomical [8,1,48,31]. Additionally, the direct and superior surgical view that results from neuroendoscopy could result in structures being viewed from different perspectives than those presented in anatomical studies, which may be confusing for the surgeon [33,35,37]. After opening the TC, the LM

characteristics must be noted and may require additional maneuvers for successful opening. In the present study, we observed a thick LM in one-third of cases, and the overture was hard in 39% of procedures. Despite the fact that a “naked basilar artery” was achieved in all cases of this sample, the difficulty during the procedure resulted in a lower ETV success rate in a long-term analysis. Furthermore, an anomalous IIIIVT floor is correlated with a higher rate of ETV failure in the first six months after the procedure and was a valid intraoperative parameter impacting the ETV success rate. This impression aligns with several reports that have considered the anatomic aspects of TC and LM and could assist surgeons in identifying procedures that may be difficult or require extra care [3,9,10,20,21,23,24,28,35,39,43,47,46,51].

Another interesting finding of our study was the significant ability of ETVSS to predict the actual ETV success as well as the level of difficulty of the LM overture, which validates the importance of this score in warning neurosurgeons about the significance of the three preoperative parameters and the associated risk of ETV failure. Additionally, difficult cases are more prone to intraoperative complications, such as severe bleeding. According to the findings of this study, the cut-off ETVSS was 50%. A high failure rate of ETV was observed in myelomeningocele patients (60%) and in patients younger than one month of life (75%). This also represents the more difficult level at which ETV must be performed in both situations, as well as the lower probability for success based on the ETVSS [20,35]. This fact could explain the variations in =predictability of ETVSS at difficult levels in our sample.

Limitations of the study and lessons to be learned

This study presented several limitations, including the absence of digital high quality radiologic data needed to compare anatomic details of TC and LM and measure the degree of ventriculomegaly, which could add relevant information about the difficult level of prediction, as well as the late radiologic outcome. Furthermore, the use of other instruments to perform ostomy by in other institutions could cause a bias in comparison with our parameters, since neurosurgeons have performed ETV with forceps instead bipolar or embolectomy catheters. Thus, further studies using different equipment, techniques, and surgeon experiences when opening the TC/LM could add more evidence to expand our findings. In spite of these limitations, the results of our study shed light on some of the factors that contribute to failure of the ETV procedure. For example, very young patients are at a greater risk, certain hydrocephalus etiologies, and the anatomic abnormalities of the IIIIVT floor.

Because this was a prospective study, the cohort in this study reflected patients that our medical center treats, which influenced a pediatric patient prevalence. Our experience is likely to differ from most medical institutions where adults and the elderly generally predominate.

Neuroendoscopic *in vivo* observations showed that the LM anatomical characteristics were variable for a considerable proportion of the time. Anatomical TC changes were associated with different LM configurations. In these situations, TC and LM anatomical characteristics may be challenging to interpret, and the surgical response may be insufficient, which can make ETVs difficult to perform successfully.

Technical difficulty arises when with the TCs are distorted and/or opaque, with thickened LMs and with the existence of a space between the TC and LM, which requires the structures to be opened separately.

Hydrocephalus is associated with congenital malformations and inflammatory processes. Bleeding increased the difficulty of opening the LM. Because these etiologies are more common in childhood, difficulty performing ETVs under these conditions may explain the higher failure rate observed among children who are younger than one month.

A higher incidence of congenital malformations among infants was observed, especially with a myelomeningocele, which generally results in a complex TC/LM relationship, as well as a thickened LM that is more difficult to open. Therefore, advanced technical expertise is necessary, and experience is advised.

Congenital malformations and "infection/parasitic" structural changes are associated with difficulty opening the LM. In these etiologies, TC anatomical changes predominate. As the degree of anatomical distortion increases, the technical difficulty of the ETV also increases.

Therefore, we can make the following assumptions, based on our findings.

- When performing ETVs, neurosurgeons have a 33% chance of encountering anomalies on the IIIVT floor, including three different characteristics: anatomical distortions, tissue alterations, and hemorrhage. In addition, this anomaly is converted with a 50% chance of failure of the procedure during the first six months after the ETV procedure, even when the LM was successfully opened.
- After opening the IIIVT floor, a neurosurgeon will find a thickened LM in one-third of cases, thereby increasing the difficulty of the surgery. TC anatomical alterations, opacity, and the degree of difficulty required to open the TC are factors that were significantly associated with difficulty opening the LM. Furthermore, in 55.6% of cases, TC and LM could not be opened simultaneously, so they needed to be opened separately. Usually, when the floor anatomy is altered, the TC and LM tend to be separated. In this situation, two distinct technical acts are required to open both structures. Additionally, the LM opening becomes more difficult to open in this circumstance, further increasing the risk of complication. Thus, these types of cases show a trend toward failure after 10 months of ETV was performed.

This procedure has a high risk of complications due to various factors. In this study, the ETVSS demonstrated that it is a valuable indicator for predicting certain difficulties based on preoperative features, such as patient age, hydrocephalus etiology, and the previous shunt, which must be recognized in advance by the neurosurgeon so that preventative techniques or alternate approaches can be implemented.

ETV is a relatively quick procedure due to its reliable anatomical references and the availability of standard techniques, so it is considered by some to be easy to perform. However, morphological difficulties are common, particularly in certain patients, such as children under two years of age.

Therefore, LM recognition and correct management must be performed each time to ensure that the ventricular system is fully opened and communicates with the subarachnoid space.

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Conflicts of interest/Competing interests

The authors have declared no competing interests.

Availability of data and material

Data not available

Code availability

Not applicable

Ethics approval

This study was approved by the ethical board with protocol number 1.515.461.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Author contributions

Conceptualization: José Aloysio da Costa Val Filho; Methodology: José Aloysio da Costa Val Filho ; Formal analysis and Investigation: José Aloysio da Costa Val Filho; Writing - Original draft preparation: Leopoldo Mandic Ferreira Furtado, Guaracy de Macedo Machado Filho, and Fernando Levi Alencar Maciel ; Writing - review and editing: Leopoldo Mandic Ferreira Furtado, José Aloysio da Costa Val Filho, ; Supervision: Sebastião Nataniel da Silva Gusmão.

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Tables

Table 1. Face validity for defining the difficulty level of opening the IIIVT floor	
Easy to open IIIVT floor	Difficult to open IIIVT floor
Perforation requires one attempt	Perforation requires more than one attempt
Embolectomy catheter was insufflated only a few times	Many maneuvers with the embolectomy balloon or other instruments were required
Cistern free and without anatomic structures interposed	Anatomic structures blocking cistern view

Table 2. Face validity for definition the difficult level to open LM	
Easy to open LM	Difficult to open LM
Open together to the floor	Close proximity to basilar artery and pontine vessels
Without additional maneuvers beyond usual if LM/TC were apart	Many maneuvers with ballon and other instruments
	Poor visibility
	Thickness
	Depth

Table 3 – Anatomical features observed during ETV	
Tuber Cinereum Appearance	Conventional/ Distorted
Translucent floor	Yes/No
Floor opening technique	Easy/Difficult
Appearance of LM	Thin/Thick
Relationship between LM and floor	Attached/Separated
LM opening 1	Opened together to the floor at the same time/Opened Separated from the floor
LM opening 2	Easy/Difficult

Table 4. Features of the 54 patients who underwent ETV

Variables	n (%)
Sex	
Male	29(53.7)
Female	25(46.3)
Age at ETV	
≤1 month	8 (14.8)
>1 to < 6 months	9 (16.7)
6 months to < 1 year	3 (5.6)
>1 to 2 years	6 (11.1)
>2 to 10 years	14 (25.9)
>10 to 19 years	4 (7.4)
>19 to 65 years	8 (14.8)
>65 years	2 (3.7)
Etiology of hydrocephalus	
Aqueductal stenosis	32 (59.3)
Non tectal brain tumors	6 (11.1)
Postinfectious	6 (11.1)
Myelomeningocele	5 (9.3)
Intraventricular hemorrhage	4 (7.4)
Pineal region tumors	1 (1.8)
Third ventricle floor is abnormal	18 (33.3)
Tuber cinereum opaque	15 (27.8)
Tuber cinereum hard to open	21 (39)
Thick Liliequist membrane	18 (33.33)
Liliequist membrane hard to open	21(39)
LM and TC opened separately	30 (55.6)
Mean duration of surgery (minutes)	52.3

Table 5. ETV success at 6 months according to age

	ETV		
Age	Success	Failure	P value
	n (%)	n (%)	
≤1 month	2 (25)	6 (75)	0.036
>1 to ≤ 6 months	7 (77.8)	2 (22.2)	
6 months to ≤ 1 year	3 (100)	0 (0)	
>1 to 2 years	3 (50)	3 (50)	
>2 to 10 years	11 (78.6)	3 (21.4)	
>10 to 19 years	2 (50)	2 (50)	
>19 to 65 years	8 (100)	0 (0)	
>65 years	1 (50)	1 (50)	
Sum	37(68.5)	17(31.5)	

Figures

Figure 1

Diverse III/VT floor characteristics. Asterisks indicate the TC. The large double arrows indicate mammillary bodies. (The thin double arrows indicate the hypothalamus). A. Normal. B Opaque. C Translucent.

Figure 2

The three primary types of IIIVT floor alterations. A - Anatomic distortion due to myelomeningocele (hypothalamic adhesences block landmark views). B - Tissue alterations in a patient with a scar (arrow). C - Several red spots due to previous hemorrhage (double small thin arrows)

Figure 3

Association between TC (right arrow) and LM (left arrow) opacity

Figure 4

Kaplan–Meyer survival curves for ETV in 54 patients stratified by difficulty in opening the tuber cinereum (A); Difficult to open the Lilliequist membrane (B), and if during ostomy, TC and LM were opened together or separately (C).

Figure 5

ROC curve of the ETVSS predicted the difficulty opening LM during ETV. The area under the curve was 0.698.

Figure 6

Liliequist membrane through the endoscopic view. Left. Thin LM diencephalic leaf (long arrow), which is separate from the TC. The basilar artery (*) is deep and not covered by the mesencephalic leaf. Right. Thick diencephalic and mesencephalic leaves. The mesencephalic portion (arrow) covers the basilar artery bifurcation.

Figure 7

Natural LM mesencephalic overture into the pre-pontine cistern