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Preoperative third ventricular bowing as a predictor of endoscopic third ventriculostomy success in obstructive hydrocephalus

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Keywords
ETV,
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ABSTRACT

Background: Endoscopic third ventriculostomy (ETV) success depends on multiple factors. Third ventricular floor bowing (TVFB) serves as an indicator of intraventricular obstruction in hydrocephalus and existence of a pressure gradient across the third ventricular floor, which is a prerequisite for a successful ETV. The authors hypothesized that patients with preoperative bowing of the 3rd ventricle would have greater success rates after ETV compared to patients lacking preoperative bowing of the 3rd ventricle.
Objective: To study the effect of preoperative bowing of the 3rd ventricle on the success rate of ETV in obstructive hydrocephalus.
Material and Methods: The authors determined success and failure for 32 ETVs performed in patients with obstructive hydrocephalus. Patient age, etiology of hydrocephalus, duration of illness, presence or absence of papilledema, intraoperative CSF pressure, and preoperative third ventricular bowing were assessed on MR imaging.
Results: Out of a total of 32 patients, 16 had preoperative bowing of the 3rd ventricular floor and 16 had no preoperative bowing. Among the 16 patients without preoperative bowing of the floor of the third ventricle, 6 (37.50%) had a successful outcome, while 10 (62.50%) experienced failure. In contrast, among the 16 patients with bowing of the floor of the third ventricle, 13 (81.25%) were successful, whereas only 3 (18.75%) failed.
Conclusion: The presence of preoperative bowing of the third ventricle significantly increased the likelihood of ETV success.

INTRODUCTION

Hydrocephalus is defined as excessive accumulation of cerebrospinal fluid within the head. It can be a congenital condition or acquired. There may be obstruction to the CSF circulation or impaired absorption, and accordingly it has been categorized into non-communicating or communicating hydrocephalus, respectively [1].

Clinically, patients present with headache, vomiting, seizures, altered sensorium,

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diplopia, upward gaze palsy, etc. In the chronic stage, it may lead to gait disturbances, cognitive decline, or urinary incontinence.

Management involves CSF diversion in the form of ventricular shunts or endoscopic third ventriculostomy (ETV). ETV bypasses the obstruction to CSF flow at the level of the aqueduct of Sylvius by creating a stoma in the floor of the 3rd ventricle [2]. ETV has a better success rate in cases of obstructive hydrocephalus than communicating hydrocephalus [3,4].

Despite ETV, 20% to 30% of cases still have treatment failure and require shunt surgery [5,6]. So research continues to determine the factors that can affect the success rate of ETV. Primarily, a scoring system was devised, known as the ETV success score (ETVSS), which was validated on 618 ETV procedures. The scoring system was based on clinical factors such as etiology, age of the patients, and any history of previous shunting in children [7]. It was further seen that even this scoring system has a higher failure rate and that various other parameters must also be included and covered [8].

This study was carried out to find the effect of preoperative bowing of the third ventricle on the success rate of ETV in patients with obstructive hydrocephalus. Globally, the incidence of hydrocephalus ranges from 0.68 to 3.16 cases per 1000 live births [9].

Ventriculoscopy was first introduced in the early 1900s. Dandy WE used a basic endoscope to perform a choroid plexectomy for treating communicating hydrocephalus. He later developed the sub-frontal approach for conducting an open third ventriculostomy. However, due to the high mortality associated with this method, Dandy eventually sought alternative treatments. In 1910, VL L'Espinasse, a urologist, attempted endoscopic management of hydrocephalus by using a cystoscope for cauterizing the choroid plexus [10,11].

The first ETV was performed in 1923 by William Mixter using a urethroscope on a child with obstructive hydrocephalus. Tracy J. Putnam later modified the urethroscope for choroid plexus cauterization. Despite early developments, the simplicity and effectiveness of shunt systems stalled advancements in ETV for 30 years. In 1947, H.F. McNickle introduced a percutaneous approach that reduced complications and increased success rates. The 1970s saw further refinements to safely enlarge the third ventricle perforation, and stereotactic frames enhanced precision. Renewed interest in ETV grew with advancements in fiber optic and lens technology, leading to modern neuroendoscopes with high-definition cameras, deflectable tips, and superior optic resolution. Recent improvements in ETV success are attributed to better patient selection, advancements in imaging, refined surgical techniques, and improved instruments [12].

Indications

ETV is increasingly employed in the management of hydrocephalus, particularly as the preferred treatment for obstructive hydrocephalus. Some experts also recommend its use in certain cases of communicating hydrocephalus, including normal pressure hydrocephalus. ETV is indicated for patients exhibiting hydrocephalus symptoms and signs, provided they have anatomical features suitable for a successful procedure. A critical requirement for safe ventriculostomy is sufficient space between the basilar artery and the clivus beneath the third ventricle floor. While ETV can be performed in selected cases across the spectrum, its success rate is notably higher in obstructive hydrocephalus compared to communicating hydrocephalus.

Factors Determining Success of ETV

Combining age, cause of hydrocephalus, and history of a previous shunt, the ETV Success Score models are in use in the treatment of childhood hydrocephalus [7]. However, it has not yet been proven that the ETV Success Score is applicable to adult hydrocephalus. Finally, the cause of hydrocephalus is difficult to assess, because there is often a combination of intraventricular and extraventricular obstructive components, thereby limiting the usefulness of these factors. Therefore, there is a clear need for other objective preoperative classification systems for both children and adults with hydrocephalus to predict success or failure prior to performing ETV, since another surgical alternative exists.

Another novel marker is preoperative bowing of the third ventricle. Third ventricular floor bowing (TVFB) is a sign of intraventricular obstruction and indicates a pressure gradient across the third ventricular floor. In theory, this feature can be used to predict the success of ETV. TVFB is typically assessed through neuroimaging, with MRI being the preferred method [13].

Some researchers have noted that deformation or "bowing" of the third ventricular floor and lamina terminalis serves as a sign of intraventricular obstructive hydrocephalus, correlating with higher success rates in ETV [14,15,16,17,18]. This "ballooning" of the third ventricle is thought to reflect a pressure difference between the ventricle and the intracranial subarachnoid space, indicating intraventricular obstructive hydrocephalus. Conversely, the absence of such bowing may suggest equalized pressure between the ventricular system and the subarachnoid space, pointing to communicating hydrocephalus [19]. Based on these observations, we hypothesized that preoperative bowing of the 3rd ventricle would exhibit a higher ETV success rate in patients with obstructive hydrocephalus compared to those without preoperative bowing of the 3rd ventricle. To test this hypothesis, a prospective comparative study was conducted at the Department of Neurosurgery, ABVIMS & Dr. RML Hospital, New Delhi.

Material and Methods

Inclusion criteria: all patients with obstructive hydrocephalus with an indication for ETV.

Exclusion criteria: communicating hydrocephalus; patients who had previously undergone ETV; patients less than 2 years of age; patients with a history of infection, history of IVH, or haemorrhage during the procedure.

Sample size: 32 patients.

Methodology

After obtaining hospital ethics committee approval and written informed consent, patients were enrolled in the study. A successful ETV was defined as resolution or improvement in clinical symptoms; the patient did not require redo surgery or ventriculo-peritoneal shunt insertion within 6 weeks of follow-up, and was not admitted for signs and symptoms attributable to hydrocephalus within 6 weeks of follow-up. A failed ETV was defined as the necessity to undergo a repeat ETV or subsequent shunting procedure.

Standards and Definitions

We considered the third ventricle "bowed" if any of the following imaging features were present on the midsagittal preoperative MR imaging study: depression of the anterior or posterior third ventricular floor below a reference line; enlargement of the supraoptic recess (indicated by downward or anterior displacement of the chiasm and/or the presence of a downward curvature in the chiasm itself); anterior curvature of the lamina terminalis (instead of its usual posterior concavity); dilation of the proximal aqueduct to a greater extent than the distal aqueduct; and enlargement of the suprapineal recess (Figure 1).

Figure 1. Diagram of the 3rd ventricle without bowing. A reference line drawn from the middle of the optic chiasm to the superior aspect of the tegmentum of the midbrain demonstrates a flat third ventricular floor (a, b). A reference line drawn from the middle of the optic chiasm to the anterior commissure reveals that the line sits anterior to the posteriorly curved lamina terminalis (c, d). The proximal aqueduct is the same size as the distal aqueduct (e). The suprapineal recess is not overhanging (f).

We used a reference line drawn from the middle of the optic chiasm to the superior-most aspect of the tegmentum of the midbrain, at its junction with the mammillary body. We considered the floor "flat" if this reference line overlaid the floor or if the floor resided superiorly to this line. We further subdivided the third ventricular floor into an anterior section (between the optic chiasm and the posterior aspect of the infundibulum) and a posterior section (between the posterior aspect of the infundibulum and the junction of the mammillary bodies and the tegmentum of the midbrain). To assess bowing of the lamina terminalis, we used a reference line drawn from the middle of the optic chiasm to the anterior commissure.

We considered the lamina terminalis flat if this reference line overlaid the lamina terminalis or if the lamina terminalis was posterior to this line, or bowed if the lamina was anterior to this line. We considered the suprapineal recess bowed if it overlaid the pineal gland inferiorly to any extent (Figure 2).

Figure 2. Diagram of a bowed third ventricle. A line drawn from the middle of the optic chiasm to the superior aspect of the tegmentum of the midbrain demonstrates depression of the anterior (b) and posterior (a) aspects of the third ventricular floor. The deformation and elongation of the optic chiasm is indicative of suprachiasmatic recess bowing (c). A line drawn from the middle of the optic chiasm to the anterior commissure reveals anterior bowing of the lamina terminalis (d). The proximal aqueduct is larger than the distal aqueduct (e). The suprapineal recess overlays the pineal gland inferiorly (f).

Surgical Technique

The rigid Karl Storz LOTA model endoscope with Hopkins 6-degree optics, having a diameter of 3.6 mm and a working channel diameter of 1.6 mm, was used.

After preoperative preparation and intubation, patients were positioned supine with the head flexed around 15-20 degrees. A burr hole was placed on the right side, about 2.5 to 3 cm lateral to the midline, just anterior to the coronal suture. The foramen of Monro was identified at the site of confluence of the thalamostriate vein, septal vein, and choroid plexus. The endoscope was negotiated through the foramen of Monro. Photographs of the floor of the third ventricle were taken. Fenestration was made in the floor of the third ventricle anterior to the basilar artery between the mammillary bodies and infundibular recess in the midline, at the most transparent site, in order to avoid injury and intraoperative bleeding. Adequate fenestration was confirmed by direct endoscopic visualisation of the basilar artery in the interpeduncular cistern. Further, on endoscopy, the edges of the fenestration were seen flapping up and down as CSF moved between the third ventricle and basal cisterns. CSF pressure was determined per-operatively.

Statistical Analysis

Categorical variables were expressed as numbers and percentages (%), while quantitative data were summarized using mean ± standard deviation (SD) and median with interquartile range (25th and 75th percentiles). To assess the normality of data distribution, the Shapiro-Wilk test was applied. For datasets that did not follow a normal distribution, non-parametric tests were used. The statistical methods employed for analysis included: (1) the Mann-Whitney test for analyzing associations involving quantitative variables that were not normally distributed, whereas the independent t-test was applied for normally distributed quantitative variables; (2) the Chi-Square test was used to examine relationships between qualitative variables, and in cases where any cell had an expected count below 5, Fisher's exact test was utilized; (3) the odds ratio, along with a 95% confidence interval (CI), was calculated to determine the likelihood of a successful outcome based on third ventricle bowing.

Data entry was performed using Microsoft Excel, and the final analysis was conducted with the Statistical Package for Social Sciences (SPSS), version 25.0 (IBM, Chicago, USA). A p-value of less than 0.05 was considered statistically significant for all tests.

Results and Observations

A total of 32 patients with obstructive hydrocephalus with an indication for ETV were included in the study.

The average age of patients was 20.5 years (range 3 years to 52 years). Of these 32 patients, 16 were less than 18 years of age and 16 were more than 18 years of age. Of the 16 patients aged <18 years, 10 had a successful outcome of ETV and in 6 patients ETV failed. Of the 16 patients aged >18 years, 9 patients had a successful outcome of ETV and in 7 patients ETV failed, with a p-value of 0.308. Of the total 32 patients, 15 were female and 17 were male. The etiology of hydrocephalus is documented in Table 1. Of these 32 patients, 16 had preoperative bowing and 16 had no preoperative bowing. Seven patients had moderate CSF pressure and 25 patients had high CSF pressure intraoperatively. Of these 7 patients with moderate CSF pressure, ETV failed in 4 patients, and of the 25 patients with high CSF pressure, ETV failed in 9 patients. So, of the total 32 patients, 19 had a successful ETV and in 13 patients ETV failed. Among the 16 patients without bowing of the third ventricle, 6 (37.50%) had a successful outcome, while 10 (62.50%) experienced failure. In contrast, among the 16 patients with bowing of the third ventricle, 13 (81.25%) were successful, whereas only 3 (18.75%) failed.

Table 1. Etiology of hydrocephalus. CP angle: cerebellopontine angle; SOL: space-occupying lesion.

Diagnosis	No. of Patients (%)
Aqueductal stenosis	9 (28.13)
CP angle SOL	4 (12.50)
Infratentorial meningioma	2 (6.2)
Pineal SOL	6 (18.75)
Posterior fossa SOL	8 (25)
Third ventricular SOL	3 (9.38)
Total	32 (100)

Association of Duration of Illness with ETV Success

With respect to the association of duration of illness (in months) with ETV success, the median (25th-75th percentile) duration of illness in successful cases was 4 (3-8) months vs. 4 (3-5) months in failed cases, with no significant association between them (p value = 0.799) (Figure 3).

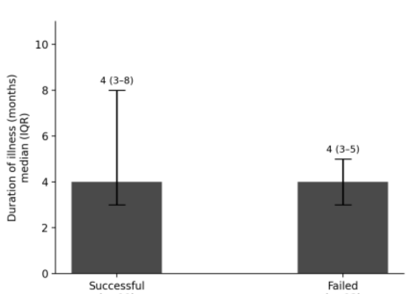

Figure 3. Association of duration of illness with success (non-parametric variable; median with 25th-75th percentile range shown).

Association of CSF Pressure with ETV Success

Among 7 patients with moderate CSF pressure, 3 (42.86%) had a successful outcome, while 4 (57.14%) experienced failure. In contrast, among 25 patients with high CSF pressure, 16 (64%) had a successful outcome, whereas 9 (36%) failed.

Overall, the total success rate across all 32 cases was 59.38% (19 out of 32), while the failure rate was 40.63% (13 out of 32). A p-value of 0.401 suggests that the difference in success rates between the moderate and high CSF pressure groups was not statistically significant, indicating that CSF pressure levels may not have a significant impact on the outcome (Figure 4).

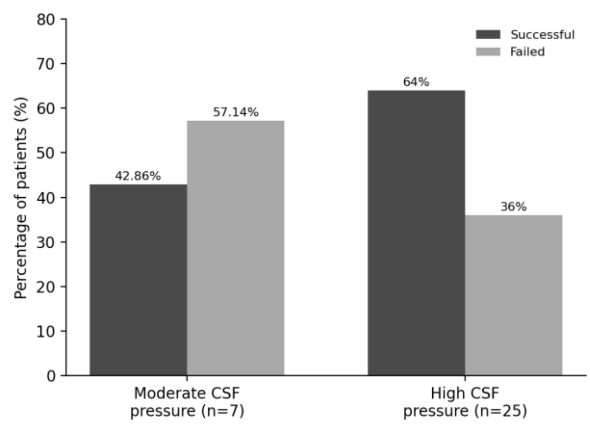

Figure 4. Association of CSF pressure with success. Chart drawn by the editor from the figures reported in the text; author to verify or supply original chart.

Association of Papilledema with ETV Success

Among 13 patients without papilledema, 5 (38.46%) had a successful outcome, while 8 (61.54%) experienced failure. In contrast, among 19 patients with papilledema, 14 (73.68%) were successful, whereas only 5 (26.32%) failed.

Overall, the total success rate across all 32 cases was 59.38% (19 out of 32), while the failure rate was 40.63% (13 out of 32). A p-value of 0.046 indicates a statistically significant difference, suggesting that the presence of papilledema is associated with a higher success rate and may positively impact outcome (Figure 5).

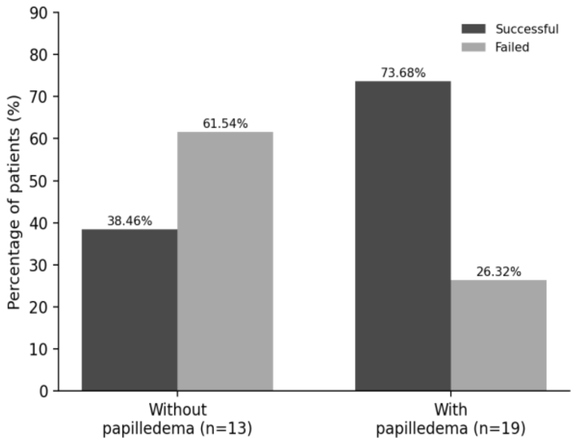

Figure 5. Association of papilledema with success. Chart drawn by the editor from the figures reported in the text; author to verify or supply original chart.

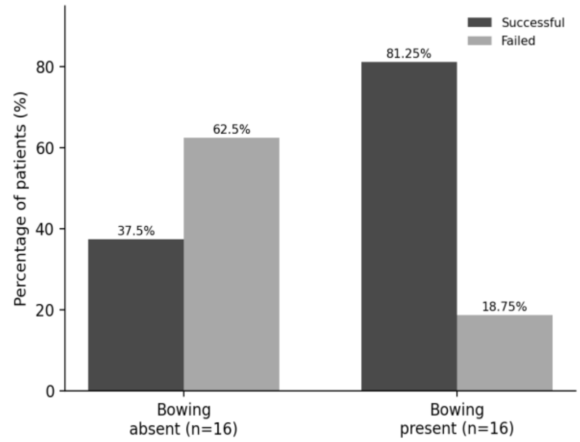

Figure 6. Association of success/failure with bowing of third ventricle. Chart drawn by the editor from the figures reported in the text; author to verify or supply original chart.

Association of Success/Failure with Bowing of Third Ventricle

Table 2 examines the relationship between the presence or absence of bowing of the third ventricle and success or failure rates. Among 16 patients without bowing of the third ventricle, 6 (37.50%) had a successful outcome, while 10 (62.50%) experienced failure. In contrast, among 16 patients with bowing of the third ventricle, 13 (81.25%) were successful, whereas only 3 (18.75%) failed.

Overall, the success rate across all 32 cases was 59.38% (19 out of 32), while the failure rate was 40.63% (13 out of 32). A p-value of 0.029 suggests a statistically significant association between bowing of the third ventricle and outcome. An odds ratio of 6.227 (1.287 to 30.124) indicates that the presence of bowing of the third ventricle had a significantly higher chance of success (Table 2, Figure 6).

Table 2. Association of success/failure with bowing of third ventricle. *Fisher's exact test.

Success /failure	Absent (n=16)	Present (n=16)	Total	P value	Odds ratio (95% CI)
Successful	6 (37.50%)	13 (81.25%)	19 (59.38%)	0.029 *	6.227 (1.287 to 30.124)
Failed	10 (62.50%)	3 (18.75%)	13 (40.63%)		1
Total	16 (100%)	16 (100%)	32 (100 %)		-

On performing multivariate regression, bowing of the third ventricle was a significant independent factor affecting success rate after adjusting for confounding factors. Patients with bowing of the third ventricle had significantly higher chances of success, with an adjusted odds ratio of 6.927 (1.243 to 38.594) for bowing of the third ventricle (p value = 0.027) (Table 3). Among all the factors, papilledema and bowing of the third ventricle showed significant association with success in the surgery (p<0.05) (Table 3).

Table 3. Multivariate logistic regression to assess significant factors affecting success rate of ETV.

Variables	Beta coefficient	Standard error	P value	Odds ratio	OR lower (95%)	OR upper (95%)
Papilledema	1.563	0.872	0.073	4.775	0.865	26.354
Bowing of third ventricle	1.935	0.876	0.027	6.927	1.243	38.594

Discussion

The present study is one of the few Indian studies conducted to determine the success rate of ETV specifically with respect to preoperative bowing of the third ventricle. We enrolled 32 patients with obstructive hydrocephalus.

Age

The mean age of the study patients was 23.06 ± 15.4 years. Proportionately, the majority of the population, i.e. 28.13%, were in the age group of 11 to 20 years.

Among other studies, Dlouhy et al. [19] conducted a study on 56 patients with hydrocephalus who underwent ETV. The patients' mean age was 30.6 years. Among the total patients, 19 were below 18 years of age and 37 were above 18 years of age. Vogel et al. [20] conducted a study on 95 patients treated with ETV, with the mean age being 19.7 years, ranging from 5 months to 77 years. The majority of patients, i.e. 51 (54%), were below 18 years, 39 (41%) were above 18 years, and only 5 (5%) were below 1 year.

In the study by Krejčí et al. [21], the group of patients older than six months consisted of 97 individuals, with an average age of 39.2 years, with a median of 42 years, ranging from 7 months to 80 years. Within this cohort, 27 were children aged between 7 months and 16 years, making up 27.8% of the total cases. Among 38 infants younger than six months, the average age was 65 days (9.28 weeks), with a median of 8 weeks, ranging from 19 to 163 days.

In the study by Wang et al. [22], out of 129 children aged 0.04 to 16 years with symptomatic hydrocephalus, there were 93% cases of obstructive hydrocephalus and 7% cases of communicating hydrocephalus. The patients' mean age was 5.84 ± 5.17 years.

ETV Success

When we specifically assessed how many of the surgeries were successful, we found that 19 (59.38%) were successful while 13 (40.63%) failed and required re-surgery.

In comparison, Dlouhy et al. [19] reported that among 56 patients with hydrocephalus, the overall success rate was 64%. Vogel et al. [20] found that in 95 patients with hydrocephalus treated with ETV, the overall success rate for ETV was 75%. In the study by Krejčí et al. [21], out of 97 patients older than six months, ETV was successful in 70 patients (72.2%), whereas it was unsuccessful in 27 (27.8%). In the study by Wang et al. [22], ETV success rate was 81%. Hilman et al. [13] carried out a systematic review and meta-analysis comprising five studies. The rate of overall surgical success was 85%.

So overall, previous studies have reported a success rate in the range of 64-85%. Our study reported a slightly lower success rate of 59.38% compared to the previously reported range, which might be because of the heterogeneous study population and various factors that may affect the success rate of ETV.

Specifically, with respect to preoperative bowing of the third ventricle, it was seen that among 16 patients without bowing of the third ventricle, 6 (37.50%) had a successful outcome, while 10 (62.50%) experienced failure, and in contrast, among 16 patients with bowing of the third ventricle, 13 (81.25%) were successful, whereas only 3 (18.75%) failed — showing that, proportionately, the presence of bowing of the third ventricle was associated with significantly higher odds of successful surgeries, with an odds ratio of 6.227.

Likewise, Dlouhy et al. [19] reported that among 56 patients with hydrocephalus, lack of anterior third ventricular preoperative bowing was significantly associated with ETV failure (adjusted hazard ratio of 2.79, $p<0.05$). In addition to evaluating the lamina terminalis and the floor of the third ventricle, they also examined the supraoptic recess and the posterior third ventricle, as these areas appeared to enlarge independently. However, none of the other specific regions, including lamina terminalis bowing, showed significant relevance.

In another study, Foroughi et al. [14] found that a significant proportion of pediatric hydrocephalus patients with preoperative convexity of the third ventricular floor experienced successful outcomes following ETV. This was in line with the findings by Vogel et al. [20], who reported that in 95 patients with hydrocephalus treated with ETV, there was a significant association between preoperative inferior bowing of the third ventricle floor on MRI and ETV success in 79% of patients ($p < 0.05$).

Even in the study by Krejčí et al. [21], a significant relationship was observed between third ventricle bowing and ETV success in patients older than six months ($p<0.05$), whereas no such correlation was found in infants younger than six months ($p>0.05$). Based on these findings, the study concluded that bowing is a key predictor of ETV success in patients over six months of age but does not hold the same significance in younger infants. Our study, in contrast to theirs, did not assess such a relationship with age.

Furthermore, our study findings were also supported by Wang et al. [22], where third ventricle floor bowing was present in all 129 patients who underwent ETV, and third ventricle floor bowing was found to be a strong predictor of ETV success. The reason was described as signifying the presence of a pressure gradient between the third ventricle and the prepontine cistern, which facilitates improved

CSF flow following the procedure. Moreover, TVFB indicates normal brain parenchymal compliance in response to elevated intraventricular pressure, a critical factor in ensuring long-term ETV effectiveness. Based on these findings, the study suggested that ETV should be the preferred treatment for patients displaying TVFB, irrespective of their ETVSS, whereas ETVSS should be utilized as an additional selection criterion for those without TVFB.

The findings were further elucidated in a meta-analysis by Hilman et al. [13], where TVFB was significantly associated with higher success rates (OR: 5.94, $p<0.05$). This finding was also supported by another systematic review and meta-analysis by Pranata et al. [3], including six studies, where there was a significant association of TVFB with higher success rates, with an odds ratio of 4.13 and a p-value below 0.05.

Overall, third ventricular floor bowing remains a significant factor positively affecting the outcomes of ETV in cases of obstructive hydrocephalus.

Limitations of the Study

The study was conducted at a single institute, which limits the generalizability of the findings to all types of study populations. The study was not conducted over a long duration of follow-up. Thus, long-term outcomes and late complications of ETV were not evaluated. Factors that can affect the success rate of ETV, such as surgeon experience and intraoperative findings, were not assessed. The study did not compare ETV with other treatment options such as ventriculoperitoneal shunting, which could provide more information on management strategies. However, the study assessed the effect of preoperative bowing of the third ventricle on the success of ETV, which is an important factor in surgical decision-making for obstructive hydrocephalus. This will help in improving outcomes.

Conclusion

The presence of preoperative bowing of the third ventricle significantly increased the likelihood of ETV success. Among patients with third ventricle bowing, 81.25% had a successful outcome, compared to only 37.50% in those without bowing. Additionally, the presence of papilledema was found to be significantly associated with a higher success rate. These results indicate that preoperative bowing of the third ventricle can serve as an important imaging predictor for ETV success, aiding neurosurgeons in patient selection and surgical planning.

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