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Investigating the Frequency of Ventriculoperitoneal Shunt Requirement in Patients Diagnosed with Normal Pressure Hydrocephalus

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ABSTRACT

Background: Normal Pressure Hydrocephalus (NPH) is a neurological condition that is distinguished by the abnormal accumulation of cerebrospinal fluid. This condition is especially prevalent in the geriatric population and is associated with cognitive decline, urinary incontinence and gait problems.

Objective: To determine the frequency of ventriculoperitoneal (VP) shunt requirement in patients diagnosed with NPH and to identify clinical, radiological and procedural factors that are predictive of successful shunt intervention.

Methods: A cross-sectional investigation was conducted on 45 patients who were diagnosed with NPH. The clinical data, which encompassed symptomatology and response to acetazolamide (AZM) and lumbar puncture (LP), were analyzed. The hippocampal atrophy, ventricular size (Evans' Index) and other pertinent markers were the primary focus of radiological assessments. The predictors of VP shunt requirement and post-shunt symptom improvement were identified using logistic regression.

Results: Insufficient improvement with LP and AZM required the implantation of a VP shunt in 22.2% (n=10) of the 45 patients. Increased ventricular size (Evans' Index; OR = 2.85, $p<0.05$) and hippocampal atrophy (OR = 3.46, $p<0.05$) were significant predictors of shunt requirement. Patients who did not exhibit symptom improvement following LP or AZM were considerably more likely to require shunt surgery ($p<0.01$). Infection (10%) and malfunction (20%) were among the complications that affected 30% of patients who underwent shunt treatment.

Conclusion: The necessity of a VP shunt in NPH patients is significantly predicted by increased ventricular size and hippocampal atrophy. The necessity of shunting is firmly suggested by the absence of symptom improvement following LP and AZM. VP shunting continues to be the most effective treatment for symptom relief in appropriately selected NPH patients, despite the associated hazards.

Keywords: *Acetazolamide; Hippocampal Atrophy; Lumbar Puncture; Normal Pressure Hydrocephalus; Ventriculoperitoneal Shunt.*

1. INTRODUCTION

A condition known as Normal Pressure Hydrocephalus (NPH) is defined by the aberrant accumulation of cerebrospinal fluid (CSF) in the brain's ventricles, which results in a range of symptoms, including cognitive decline, urinary incontinence and gait disturbances [1-2]. However, the clinical symptoms are the result of the progressive ventricular enlargement, which exerts pressure on the adjacent brain tissues, despite the normal CSF pressure readings. The elderly are the primary demographic affected by NPH and its prevalence is on the rise in tandem with the ageing population [3-4]. NPH is believed to affect up to 6% of elderly individuals; however, it frequently goes undiagnosed due to its symptom overlap with other neurodegenerative conditions, including Parkinson's disease and Alzheimer's disease [5].

The surgical implantation of a ventriculoperitoneal (VP) shunt is the definitive treatment for NPH. This device redirects surplus cerebrospinal fluid from the ventricles to the peritoneal cavity, where it can be absorbed [6-7]. This intervention has been demonstrated to enhance the quality of life and alleviate symptoms in significant number of patients. Nevertheless, the decision to proceed with the placement of VP shunt is intricate and need thorough evaluation of the potential benefits and risks [8]. The procedure is associated with the variety of complications, such as shunt malfunction, infection, subdural hematomas and over-drainage of CSF, despite its efficacy. Consequently, it is imperative to identify the patients who are most likely to benefit from shunt surgery in order to optimize outcomes and reduce superfluous risks [9-10].

The difficulty in managing NPH is the precise diagnosis and selection of suitable candidates for shunting. Although the classic triad of symptoms, gait disturbances, urinary incontinence and cognitive impairment offers the clinical framework for diagnosis, these symptoms are not exclusive to NPH and can be observed in other conditions that affect the elderly [11-12]. Magnetic resonance imaging (MRI) and computed tomography (CT) scans are employed to detect ventricular enlargement. However, the extent of ventricular dilation does not always predict the response to shunting or the severity of symptoms. To overcome this diagnostic obstacle, different supplementary tests, including lumbar puncture, external lumbar drainage and CSF infusion studies, have been implemented to identify patients who respond to shunts. But these tests may occasionally produce inconclusive results [13].

Further investigation is required to determine the frequency and predictors of VP shunt requirement in this patient population, given the intricacies of NPH diagnosis and management. It is imperative to comprehend the factors that influence the decision to proceed with shunt surgery, as well as the outcomes of those who undergo the procedure, in order to enhance patient care and clinical guidelines. Therefore, aim of this investigation was to ascertain the frequency of ventriculoperitoneal shunt requirement in patients diagnosed with Normal Pressure Hydrocephalus and to identify the clinical, radiological and procedural factors that predict successful shunt intervention.

2. MATERIALS AND METHODS

Study Design

This cross-sectional observational analysis was to determine the frequency of ventriculoperitoneal shunts required in patients diagnosed with Normal Pressure Hydrocephalus. The study also aimed to identify clinical, radiological and procedural factors that may predict successful outcomes following VP shunt intervention. The research was conducted at DHQ Teaching Hospital, Dera Ismail Khan and was approved by the institutional review board. All patient data was anonymized and processed in accordance with ethical standards.

Study Population

The research population was 45 patients who were diagnosed with NPH and presented to the outpatient department (OPD) of DHQ Hospital, during the study period from January 2023 to December 2023. The clinical presentation of these patients was consistent with NPH, which typically included gait disturbances, urinary incontinence and cognitive decline.

Inclusion Criteria

- Patients diagnosed with NPH on the basis of symptoms and radiological findings.
- Patients who underwent evaluation with lumbar puncture (LP) and treatment with acetazolamide (AZM).

Exclusion Criteria

- Patients who have experienced cerebrovascular accidents (CVAs) and were experiencing symptoms similar to those of NPH.
- Patients whose symptoms were attributable to other neurological disorders.

Data Collection

The variables noted below were extracted:

- Demographic Information: Age, sex and pertinent medical history.
- Clinical Data: Initial treatments (LP and AZM) and symptoms present.
- Radiological Data: Imaging findings from computed tomography (CT) or magnetic resonance imaging (MRI), with an emphasis on periventricular white matter alterations and ventricular enlargement.
- Procedural Data: Information on the placement of a VP shunt, if applicable, as well as the opening pressure and response to CSF drainage from lumbar puncture procedures.
- The improvement of symptoms following the placement of VP shunt, AZM treatment or LP, as well as any complications associated with these interventions.

Intervention and Outcome Measures

Initially, patients were administered LP and AZM to regulate CSF pressure and determine the necessity of additional intervention. Insufficient improvement with LP and AZM necessitated the implantation of a VP shunt in 10 of the 45 patients diagnosed with NPH. The other 35 patients were able to alleviate their symptoms through these conservative treatments and did not require shunt surgery.

The study cohort's frequency of VP shunt requirement served as the primary outcome measure. Secondary outcomes encompassed the identification of clinical, radiological and procedural factors that were linked to the decision to proceed with shunt placement.

Statistical Analysis

The demographic, clinical and radiological characteristics of the sample population were summarized using descriptive statistics. The frequency of VP shunt requirement was determined, and univariate analysis was employed to analyze the factors that were associated with the need for a shunt. In order to identify independent predictors of the efficacy of VP shunt placement, a multivariate logistic regression was implemented.

3. RESULTS

The demographic and bassline features of the patients were comparable with slight and non-significant variations. The average age of patients who required the VP shunt was marginally higher (75.1 ± 7.9 years) than that of patients who did not require the procedure (71.5 ± 8.7 years) ($p>0.05$). The distribution of sex between the two groups did not reveal any significant difference, with males comprising 70% of the shunt-required group and 60% of the non-shunt group ($p>0.05$). Although the shunt-required group exhibited higher incidence of gait disturbance, urinary incontinence and cognitive decline in terms of clinical symptoms, none of these differences reached statistical significance. The prevalence of other conditions, including hypertension, diabetes mellitus, hyperlipidaemia and smoking history, did not exhibit any statistically significant differences between the groups ($p>0.05$) (Table 1).

The distribution of symptoms in the study population were also studied, whereby, the most common symptom was gait disturbance, present in 88.9% of all patients. It was universally observed in those who required a VP shunt, with a 100% prevalence. Urinary incontinence and cognitive decline were also prevalent, affecting 73.3% and 84.4% of the patients, respectively. The shunt-required group exhibited slightly higher prevalence of both symptoms (90%). Other symptoms, including headaches, visual disturbances, vertigo and depression, anxiety, were less prevalent and exhibited only minor variations between the groups. These results indicated that the presence of gait disturbance, urinary incontinence and cognitive decline, which are critical characteristics of NPH, did not necessarily indicate the necessity of a VP shunt. This is due to the fact that these symptoms were also observed in patients who did not require the procedure (Figure 1).

There were substantial differences in radiological characteristics between patients who needed a VP shunt and those who did not. It is important to note that the ventricular size, as measured by Evans' Index, was substantially larger in the shunt-required group (0.36 ± 0.04) than in the non-shunt group (0.32 ± 0.05) ($p<0.05$). This finding suggested the strong association between the necessity for shunt placement and increased ventricular size. Furthermore, the shunt-required group exhibited a substantially higher prevalence of hippocampal atrophy (60% vs. 25.7%, $p<0.05$), which implied that it may serve as a viable indicator of a more severe condition requiring intervention. The shunt-required group exhibited a trend towards a higher prevalence of other radiological features, including periventricular white matter alterations, corpus callosum thinning and MRI flow voids; however, these differences were not statistically significant. These results emphasized the significance of specific radiological findings, such as ventricular size and hippocampal atrophy, in determining the implantation of VP shunt in NPH patients (Table 2).

The lumbar puncture (LP) opening pressure was marginally higher in patients who required a VP shunt (205 ± 30 mmH_2O) than in those who did not (185 ± 37 mmH_2O). However, this difference was not statistically significant ($p>0.05$). Importantly, none of the patients who required the VP shunt exhibited symptom improvement following LP or acetazolamide (AZM) treatment. Conversely, 100% and 51.4% of the non-shunt group improved with LP and AZM, respectively, with highly significant p-values ($p<0.05$). The procedural risks associated with shunt implantation were underscored by the 30% complication rate of VP shunt group, which included 10% shunt infection rate and 20% malfunction rate (Table 3).

The VP shunt group exhibited higher prevalence of specific radiological features, despite the fact that all patients exhibited ventricular enlargement (100%), as is typical in NPH. Sylvian fissure dilatation and a reduced callosal angle (<90°) were more prevalent in the shunt group, although the difference was not statistically significant. The shunt group also exhibited a higher frequency of white matter hyperintensities and flow voids in the aqueduct or fourth ventricle. This suggested a potential correlation with the necessity for shunt installation. Nevertheless, none of these variations achieved statistical significance, suggesting that even though these radiological features may be associated with the severity of the disease, they are not sufficient to predict the need for a shunt individually (Table 4).

Multivariate logistic regression analysis indicated that ventricular size (Evans' Index) and hippocampal atrophy were

significant predictors of the need for VP shunt, with odds ratios of 2.85 and 3.46 ($p<0.05$). Furthermore, the absence of symptom alleviation following LP and AZM treatment is a strong predictor of the necessity for a shunt, as evidenced by the highly significant p-values ($p<0.05$) and the extremely low odds ratios (0.01 for LP and 0.07 for AZM). The significance of both radiological markers and response to conservative treatments in predicting the necessity of a shunt in NPH patients was emphasized by these findings (Table 5).

Significant predictors of symptom improvement following the placement of a VP shunt was observed. The odds ratios of symptom improvement were 3.22 and 4.33 ($p<0.05$) for ventricular enlargement (Evans' Index) and hippocampal atrophy. Conversely, the odds of post-shunt improvement were lower when symptoms improved after LP and AZM treatment prior to shunting, with odds ratios of 0.08 ($p = 0.015$) and 0.11 ($p = 0.018$), respectively. These findings indicated that specific radiological findings were critical indicators of favorable shunt outcomes, whereas a dearth of response to less invasive treatments may suggest a more favorable response to shunting (Table 6).

Table 1: Demographic and Clinical Characteristics of the Study Population

Parameter	Total (n=45)	VP Shunt Required (n=10)	No VP Shunt Required (n=35)	Chi-Square Value	p-value
Age (years)	72.3 ± 8.6	75.1 ± 7.9	71.5 ± 8.7	1.413	0.234
Sex (Male)	28 (62.2)	7 (70)	21 (60)	0.389	0.536
Sex (Female)	17 (37.8)	3 (30)	14 (40)	0.389	0.536
Gait Disturbance	40 (88.9)	10 (100)	30 (85.7)	1.187	0.278
Urinary Incontinence	33 (73.3)	9 (90)	24 (68.6)	1.791	0.181
Cognitive Decline	38 (84.4)	9 (90)	29 (82.9)	0.225	0.637
Hypertension	26 (57.8)	7 (70)	19 (54.3)	0.721	0.396
Diabetes Mellitus	18 (40.0)	5 (50)	13 (37.1)	0.578	0.446
Hyperlipidemia	22 (48.9)	6 (60)	16 (45.7)	0.660	0.417
Smoking History	12 (26.7)	4 (40)	8 (22.9)	1.204	0.273

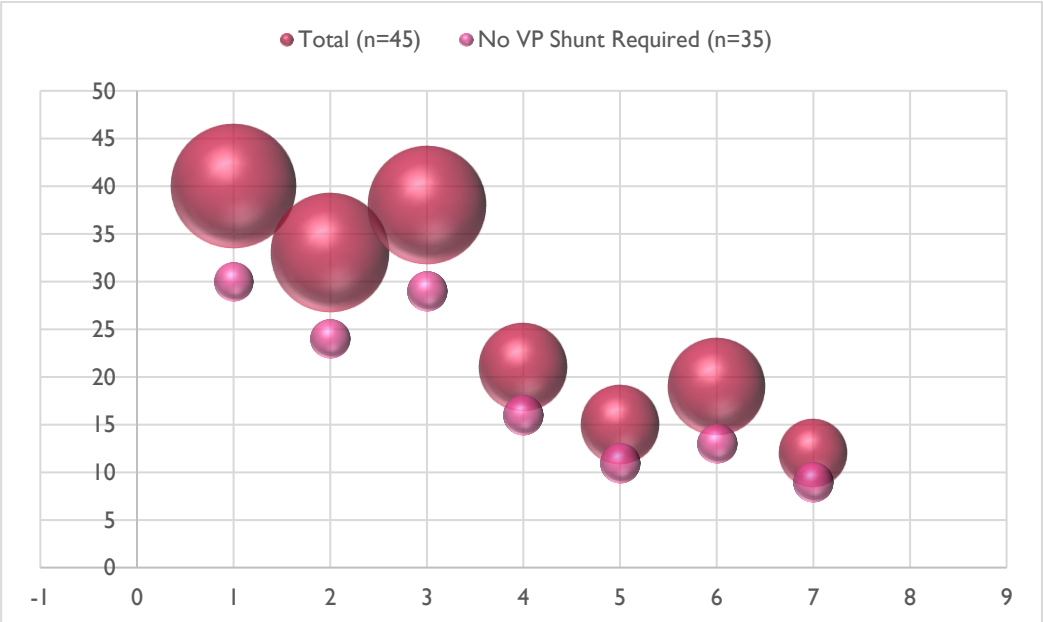

Figure 1: Distribution of Symptoms in Patients with NPH

Table 2: Radiological Characteristics and Findings

Radiological Parameter	Total (n=45)	VP Shunt Required (n=10)	No VP Shunt Required (n=35)	Chi-Square Value	p-value
Ventricular Size (Evans' Index)	0.33 ± 0.05	0.36 ± 0.04	0.32 ± 0.05	5.006	0.025*
Periventricular White Matter Changes	38 (84.4)	9 (90)	29 (82.9)	0.225	0.637
Hippocampal Atrophy	15 (33.3)	6 (60)	9 (25.7)	4.332	0.037*
Corpus Callosum Thinning	11 (24.4)	4 (40)	7 (20)	1.566	0.211
MRI Flow Void	30 (66.7)	9 (90)	21 (60)	3.230	0.072

Table 3: Procedural Data and Outcomes

Procedural Parameter	Total (n=45)	VP Shunt Required (n=10)	No VP Shunt Required (n=35)	Chi-Square Value	p-value
Lumbar Puncture Opening Pressure (mmH_2O)	190 ± 35	205 ± 30	185 ± 37	2.481	0.115
Symptom Improvement After LP (%)	35 (77.8)	0 (0)	35 (100)	42.85	0.001*
Acetazolamide Response (%)	18 (40)	0 (0)	18 (51.4)	8.85	0.003*
VP Shunt Complications (%)	-	3 (30)	-	-	-
Shunt Infection Rate (%)	-	1 (10)	-	-	-
Shunt Malfunction Rate (%)	-	2 (20)	-	-	-

Table 4: Radiological Assessment of NPH Patients

Radiological Parameter	Total (n=45)	VP Shunt Required (n=10)	No VP Shunt Required (n=35)	Chi-Square Value	p-value
Ventricular Enlargement	45 (100)	10 (100)	35 (100)	-	-
Sylvian Fissure Dilatation	30 (66.7)	8 (80)	22 (62.9)	1.004	0.316
Callosal Angle (<90°)	22 (48.9)	7 (70)	15 (42.9)	2.129	0.144
Cerebral Atrophy	20 (44.4)	6 (60)	14 (40)	1.125	0.289
White Matter Hyperintensities	31 (68.9)	9 (90)	22 (62.9)	2.977	0.084
Aqueductal Stenosis	8 (17.8)	3 (30)	5 (14.3)	1.225	0.269
Flow Void in Aqueduct or Fourth Ventricle	29 (64.4)	9 (90)	20 (57.1)	3.225	0.073

Table 5: Multivariate Logistic Regression Analysis of Predictors for VP Shunt Requirement

Predictor Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
Age (per year increase)	1.05	0.98 - 1.13	0.1941
Ventricular Size (Evans' Index)	2.85	1.19 - 6.84	0.019*
Hippocampal Atrophy	3.46	1.01 - 11.86	0.048*
Lumbar Puncture Opening Pressure (per 10 mmH2O increase)	1.10	0.99 - 1.22	0.067
Symptom Improvement After LP	0.01	0.00 - 0.12	0.001*
Acetazolamide Response	0.07	0.01 - 0.55	0.012*

Table 6: Logistic Regression Analysis of Clinical and Radiological Predictors of Symptom Improvement Post-Shunt

Predictor Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
Age (per year increase)	0.95	0.87 - 1.03	0.219
Gait Disturbance	2.14	0.76 - 6.01	0.149
Ventricular Enlargement (Evans' Index)	3.22	1.08 - 9.57	0.037*
Hippocampal Atrophy	4.33	1.21 - 15.46	0.024*
White Matter Hyperintensities	1.89	0.67 - 5.28	0.235
Symptom Improvement After LP	0.08	0.01 - 0.60	0.015*
Acetazolamide Response	0.11	0.02 - 0.69	0.018*

4. DISCUSSION

The objective of this investigation was to determine the frequency of ventriculoperitoneal shunt requirement in patients diagnosed with Normal Pressure Hydrocephalus and to identify clinical, radiological and procedural predictors of successful shunt intervention. The elderly population faces a distinctive challenge with NPH, which is defined by the triad of gait disturbance, urinary incontinence and cognitive decline, as a result of the confluence of its symptoms with other neurodegenerative conditions. Our results are in support of the most effective approach to managing NPH, particularly in the identification of patients who are most likely to benefit from VP shunting.

Following the failure of initial conservative treatments (lumbar puncture and acetazolamide) to alleviate symptoms in our cohort of 45 patients diagnosed with NPH, 22.2% (n=10) required VP shunt placement. This frequency is in accordance with prior research, which indicated that approximately 20-30% of NPH patients may ultimately need shunt surgery after noninvasive measures have been implemented. Exhaustionediation in reported shunt rates across various studies emphasizes the complexity of NPH diagnosis and the difficulty of predicting which patients will benefit from shunt placement [14]. Our research lends credence to the idea that, although a substantial number of NPH patients respond to conservative management, a subset with more severe disease progression or less favorable radiological features may need surgical procedure [14-15].

Our examination of clinical characteristics demonstrated that patients needing shunt placement were slightly older. The absence of substantial differences in age, sex and comorbidities, including hypertension and diabetes, between the shunt and non-shunt groups implied that these demographic factors are not the primary determinants of the necessity of a shunt. Rather, the symptom response to initial interventions seems to be a more dependable predictor. In contrast to the non-shunt group, none of the patients who required a VP shunt demonstrated symptom improvement following lumbar puncture or acetazolamide treatment. This discovery is in accordance with prior research that has demonstrated that a subpar response to CSF drainage tests is a reliable indicator of the necessity for shunt surgery [16-18].

The high-sensitivity response's ability to predict conduit outcomes has been extensively documented. The findings of a study

conducted by Chau et al. (2019) indicated that patients who demonstrated substantial relief in their symptoms following CSF drainage were significantly less likely to require shunting [19]. Our results are consistent with these, which reinforce the value of lumbar puncture as a diagnostic instrument for evaluating the candidacy of a shunt in patients with NPH. The pharmacologic response's function in guiding treatment decisions is further substantiated by the absence of symptom improvement in the shunt-required group following acetazolamide treatment. Acetazolamide, which diminishes the production of cerebrospinal fluid, has been suggested as an alternative or adjunctive therapy for NPH [20]. Our research indicated that patients who do not respond to acetazolamide may have a more advanced disease that needing surgical intervention.

The shunt requirement and outcomes were significantly predicted by radiological findings. In our investigation, we discovered that the necessity for VP shunt was substantially correlated with an increase in ventricular size, as assessed by the Evans' Index. This discovery is in accordance with the widely accepted notion that ventricular enlargement is a distinguishing feature of NPH, as it is indicative of the accumulation of cerebrospinal fluid within the brain's ventricles. Another substantial predictor of shunt requirement was hippocampal atrophy, which implies that patients with more severe disease may require surgical intervention due to more pronounced brain structural changes [21].

Numerous studies have investigated the potential of ventricular dimensions to predict shunt outcomes. Said et al. (2023) found that a higher likelihood of shunt responsiveness was associated with a larger ventricular size [23]. Similarly, our results indicated that patients with parietal ventricular enlargement are more likely to benefit from shunting, which is likely a result of the more pronounced effects of cerebrospinal fluid accumulation on brain tissue. Nevertheless, it is crucial to recognize that ventricular size is a valuable predictor; however, it should not be employed in isolation. The absence of substantial differences in other radiological markers, such as white matter hyperintensities and corpus callosum reduction, suggests that a comprehensive radiological assessment is essential for the accurate diagnosis and treatment planning [23].

It is intriguing that our investigation discovered that the shunt-required group exhibited a higher prevalence of white matter hyperintensities and MRI flow defects. The predictive value of white matter changes in NPH has been the subject of conflicting results in previous studies. Some researchers have proposed that white matter hyperintensities may suggest a more advanced disease and a worse prognosis, while others have not found a distinct correlation between changes and shunt outcomes [24]. The non-significant trend observed in our study implies that white matter alterations may be correlated with the severity of the disease; however, they are not definitive predictors of the necessity of a shunt.

The hazards associated with the placement of a VP shunt are underscored by the procedural outcomes in our study. In 30% of patients who underwent a shunt, complications occurred, including a 10% infection rate and a 20% malfunction rate. These results are consistent with prior investigations of complications associated with shunts, which continue to be a significant issue in the treatment of NPH [6]. The significance of patient selection and the necessity of a comprehensive preoperative assessment to reduce surgical risks are emphasized by the relatively high rate of complications.

Despite the risks, VP shunting continues to be the most effective treatment for NPH, with a significant reduction in symptoms for many patients during the postoperative period. Our research revealed that patients with more severe structural alterations are more likely to benefit from surgical intervention, as symptom improvement following shunting was correlated with increased ventricular size and hippocampal atrophy. Nevertheless, the necessity of continuous monitoring and management of shunt function to guarantee long-term success is underscored by the presence of complications.

The generalizability of our findings may be restricted by the single study area and relatively small sample size. In order to verify our findings and further clarify the factors that influence the efficacy of shunts, future research should concentrate on larger, prospective studies with extended follow-up periods.

5. CONCLUSION

The importance of comprehensive clinical and radiological evaluations in determining the need for VP shunt placement in patients with NPH was underscored by this study. The significant association between the necessity for shunting and increased ventricular size (Evans' Index) and hippocampal atrophy is one of the key findings. However, the absence of symptom alleviation following lumbar puncture and acetazolamide treatment strongly indicates the necessity for surgical intervention. VP shunting continues to be the most effective treatment for symptom relief in appropriately selected NPH patients, despite the procedural hazards, which include a 30% complication rate. These findings emphasize the significance of precise diagnostic criteria and patient selection in order to optimize outcomes in the management of NPH.

Conflict of Interest

None.

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