



## Research

# Evaluation of Patients with Idiopathic Normal Pressure Hydrocephalus Undergoing Surgical Treatment Using the Evans Index and Mini-Mental Status Examination

## İdiopatik Normal Basıncılı Hidrosefali Tanısı ile Cerrahi Tedavi Uygulanan Hastaların Evans İndeksi ve Mini Mental Durum Testi ile Değerlendirilmesi

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### ABSTRACT

**Objective:** Normal pressure hydrocephalus (NPH) is a chronic, progressive condition primarily affecting elderly patients. Based on etiology, NPH is categorized into two subtypes: secondary NPH and idiopathic NPH (iNPH). This study focused only on patients with iNPH, aiming to identify critical considerations in diagnosis, treatment, and postoperative follow-up.

**Methods:** This retrospective study analyzed data from 45 patients diagnosed with iNPH who underwent programmable ventriculoperitoneal shunt implantation between 2016 and 2024. Parameters evaluated included patient demographics, presenting symptoms, duration of symptoms before surgery, comorbidities, preoperative and postoperative Evans indices, shunt pressures, urinary incontinence, gait improvement, changes in preoperative subarachnoid space, ventricular dimensions, postoperative complications, and Mini-Mental State Examination (MMSE) scores.

**Results:** The findings underscored the importance of multidisciplinary follow-up in elderly patients with comorbidities, the role of MMSE scores in assessing cognitive status preoperatively and postoperatively, and the limited utility of the Evans index as a postoperative marker. Adjusting shunt pressure was shown to play a crucial role in minimizing complications.

**Conclusion:** In this highly sensitive patient population, timely and appropriate shunt surgery significantly enhances quality of life and reduces caregiver burden.

**Keywords:** Hydrocephalus, ventriculoperitoneal shunt, postoperative follow-up

### ÖZ

**Amaç:** Normal basıncılı hidrosefali (NPH), yaşlı hastalarda görülen ve sürekli ilerleyen kronik bir hastalıktır. Hastalığın nedenine bağlı olarak, iki alt tipe ayrılır; ikincil NBH ve primer veya idiyopatik NBH (iNBH). Bu çalışmada sadece iNPH'li hastalara odaklanılmış olup, tanı, tedavi ve ameliyat sonrası takipte kritik hususların belirlenmesi amaçlanmıştır.

**Gereç ve Yöntem:** 2016-2024 tarihleri arasında 45 iNPH tanısı alan ve prognozlanabilir ventriküloperitoneal şant implante edilen hastalar retrospektif olarak değerlendirildi. Hastaların cinsiyetleri, yaşları, şikayetleri, operasyona kadarki şikayet süreleri, ek hastalıkları, preoperatif ve postoperatif Evans indeksleri, şant basınçları, idrar inkontinansı ve yürümelerindeki düzelmeleri, preoperatif subaraknoid mesafede artış olup olmadığı, postoperatif ventrikül boyutlarında genişleme olup olmadığı, postoperatif komplikasyonlar ve preoperatif ve postoperatif yapılan Mini Mental Durum Muayenesi (MMDM) değerlendirildi.

**Bulgular:** Özellikle comorbiditeleri olan yaşlı hastaların multidisipliner takip edilmesi, preoperatif ve postoperatif dönemdeki takiplerinde MMDM skorlarının önemi, preoperatif önemli tanı kriteri olan Evans indeksinin postoperatif anlamlı bir belirteç olmadığı, şant basıncı ayarının hastaların komplikasyon gelişmemesindeki önemini ortaya koymaya çalıştık.

**Sonuç:** Oldukça hassas özellikler taşıyan bu hasta grubunda başarılı, zamanında ve endikasyonlara göre uygulanacak şant cerrahisi, hastaların yaşam kalitesini önemli ölçüde artırabilir ve sonuç olarak onlara bakanların yükünü hafifletebilir.

**Anahtar Kelimeler:** Hidrosefali, ventriküloperitoneal şant, postoperatif izlem

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## INTRODUCTION

Idiopathic normal pressure hydrocephalus (iNPH) is a chronic, progressive condition commonly seen in the elderly. First described in 1964 by Colombian neurosurgeon Salomón Hakim Doe (1911-2008) and subsequently detailed by Hakim and American neurosurgeon Raymond D. Adams (1911-2008) in 1965, NPH is characterized by ventriculomegaly with normal cerebrospinal fluid (CSF) pressure. It is classified into secondary NPH (sNPH) and iNPH subtypes, with iNPH often presenting without an identifiable cause.

iNPH is commonly associated with intracranial hemorrhage, craniocerebral trauma (e.g., traumatic brain injury), purulent-inflammatory processes within the cranial cavity, and prior brain surgeries. Despite these associations, the exact etiology of iNPH remains controversial, with vascular, biomechanical, hereditary, inflammatory, and metabolic factors being frequently implicated. Moreover, reliable biological markers for iNPH have yet to be identified. The condition is characterized by a classic clinical triad: gait disturbances, dementia, and urinary incontinence (1,2). According to the largest prevalence study, iNPH occurs in 0.2% of individuals aged 70-79 and 5.9% of those over 80 years (3).

Radiologically, ventriculomegaly is the most significant finding in iNPH, with an Evans index exceeding 0.3. Additional features include widening of the Sylvian fissure, steepening of the callosal angle, narrowing of the high parietal convexity, and widening of the subarachnoid spaces. However, these radiological findings are not exclusive to iNPH as they are present in 64% of NPH cases with a positive predictive value of 77% and a negative predictive value of 25.9% (4).

Neurology and neurosurgery must collaborate to diagnose NPH accurately. Distinguishing NPH from other conditions that cause progressive dementia and present with similar clinical symptoms, such as atherosclerotic encephalopathy, is particularly challenging. Accurate diagnosis is critical before initiating shunt treatment, as it prevents unnecessary surgical interventions and associated complications. Importantly, iNPH, a condition seen predominantly in older adults, is considered a treatable psychomotor disorder. For these patients, shunt surgery plays a vital role in improving their quality of life.

## METHODS

This retrospective study evaluated 45 patients diagnosed with iNPH and treated with programmable ventriculoperitoneal (VP) shunts between 2016 and 2024. Patients with sNPH were

excluded. Ethics committee approval was obtained before data collection. Patient data were retrieved from hospital records, outpatient clinic evaluations, and information provided by the relatives.

Data collected included demographic characteristics, presenting symptoms, duration of symptoms before surgery, comorbidities, preoperative and postoperative Evans indices, shunt pressures, and outcomes related to urinary incontinence and gait improvement. Additionally, the presence of preoperative subarachnoid space expansion, postoperative ventricular dimension changes, complications, and Mini-Mental State Examination (MMSE) scores was recorded.

All patients underwent comprehensive evaluations by neurology and neurosurgery teams before surgery. The diagnosis of iNPH was confirmed, and patients were closely monitored by both departments postoperatively. Each patient received an implantable programmable VP shunt.

Furthermore, the study statistically analyzed patient survival rates in the presence of shunt-related complications. Preoperative and postoperative Evans index, and MMSE scores were compared, and percentage changes in Evans index values were evaluated in relation to postoperative recovery outcomes.

The study was approved by the Ethics Committee of University of Health Sciences Türkiye, Bursa High Specialization Training and Research Hospital (approval no: 2024-TBEK 2024/06-01, date: 12.06.2024). Written informed consent was obtained from all participants or their legal guardians.

### Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 28.0.0.0 (IBM Corp., USA). The Shapiro-Wilk test was used to assess the normality of variable distribution. Normally distributed variables were reported as mean±standard deviation, whereas nonnormally distributed variables were presented as median (minimum-maximum). Since the data did not follow a normal distribution, the Mann-Whitney U test was used for comparing numerical variables between independent groups, while the Wilcoxon signed-rank test was applied for dependent groups. Categorical variables were expressed as counts and percentages. Relationships between variables were analyzed using Spearman's correlation coefficient. A two-tailed p-value of <0.05 was considered statistically significant.

## RESULTS

Among the 45 patients included in the study, 27 (60%) were male, and 18 (40%) were female. The mean age of

the cohort was  $70.04 \pm 7.15$  years (range: 46-85 years). The mean follow-up period was 2.48 years, and the mean duration of complaints before surgery was 12.00 (range: 6.00-48.00 months). All patients underwent implantation of programmable VP shunts, with a median shunt pressure of 100 mmH<sub>2</sub>O (range: 100-130 mmH<sub>2</sub>O). During the follow-up period, 15 (33.3%) patients died due to unrelated health complications (Tables 1 and 2).

The primary complaints reported were as follows: 36 (80%) patients presented with the triad of gait disturbance, dementia, and urinary incontinence; six (13.3%), patients reported gait disturbance alone; one (2.22%), patient exhibited the triad with imbalance; one (2.22%), patient presented with headache and gait disturbance; and one

(2.22%), patient showed a combination of gait and speech disorders (Table 1).

The most common comorbidities observed were hypertension in 15 (33.33%) patients and diabetes in 12 (26.67%) patients, followed by cerebrovascular disease in nine (20%), coronary artery disease in eight (17.78%), dementia in six (13.33%), Parkinson's disease in four (8.89%), epilepsy, anxiety disorder, depression, and Alzheimer's disease each in three (6.67%). Cognitive disorders and bipolar disorder were noted in two (4.44%) patients each (Table 2).

Preoperative imaging showed subarachnoid space expansion in 30 (66.7%) patients, partial expansion in 14 (31.1%) patients, and no expansion in one (2.22%) patient (Table 3). Postoperatively, gait disturbance improved in 40 (88.9%) patients, and urinary incontinence improved in 22 (48.9%) patients. An increase in ventricular dimensions was observed in 18 (40%) patients (Table 3), and complications occurred in six (13.3%) patients (Table 2). Subdural hemorrhage was reported in four (66.7%) patients, and shunt dysfunction required revision in two patients (Table 3). The shunt pressures of our patients who developed subdural hemorrhage were set to 110 mmH<sub>2</sub>O. To address subdural hemorrhage, shunt pressures were increased to 130 mmH<sub>2</sub>O in five patients, and no further hemorrhages were observed following this adjustment.

Preoperative and postoperative Evans index values were 0.34 (range: 0.20-0.72) and 0.34 (range: 0.21-0.65), respectively, with no significant difference noted ( $p=0.821$ ). Preoperative MMSE values were 19.00 (range: 5-26), while postoperative values were 15.50 (range: 7-26); this change showed no significant difference ( $p=0.506$ ). While Evans index values decreased in 20 patients, an increase was noted in 25 patients (Table 4). Notably, despite increased Evans index values in 25 patients, 21 showed improvements in walking ability, and 13 experienced improved urinary incontinence.

**Table 1.** Patient characteristics

Variable	Descriptive statistics
Age (year)*	70.04±7.15
<b>Gender†</b>	
Female	18 (40)
Male	27 (60)
Complaint period‡ (months)	12.00 (6.00-48.00)
Shunt pressure (mmH <sub>2</sub> O)	100.00 (100.00-130.00)
<b>Patient complaints</b>	
Triad‡	36 (80.0)
Walking disorders‡	6 (13.3)
Triad and imbalance‡	1 (2.22)
Headache and walking disorders‡	1 (2.22)
Walking disorders and speech disorders‡	1 (2.22)

\*: Mean±standard deviation, †: Median (minimum-maximum), ‡: n (%)

**Table 2.** Patient comorbidities, survival and shunt complications of the patients

Comorbidity	n	%
Parkinson's disease	4	8.89
Dementia	6	13.33
Epilepsy	3	6.67
Cognitive disorders	2	4.44
Cerebrovascular disease	9	20.00
Hypertension	15	33.33
Diabetes	12	26.67
Bipolar disorder	2	4.44
Anxiety disorder	3	6.67
Coronary artery disorder	8	17.78
Depression	3	6.67
Alzheimer's disease	3	6.67
Exitus	15	33.3
Shunt complications	6	13.3

**Table 3.** Postoperative outcomes

Variable	n	%
<b>Improvement in walking</b>	40	88.9
<b>Improvement in urinary incontinence</b>	22	48.9
<b>Increase in postoperative ventricular size</b>	18	40.0
<b>Enlargement of subarachnoid spaces (preoperative)</b>	No	1 2.2
	Yes	30 66.7
	Partially	14 31.1
<b>Postoperative complications</b>	Subdural hemorrhage	4 66.7
	Shunt revisions	2 33.3
	Total	6 100.0

These findings suggest that the Evans index is not a reliable predictor of clinical benefits from shunt treatment.

When postoperative Evans indices were analyzed in relation to walking improvement, urinary incontinence, increases in ventricular dimensions, preoperative subarachnoid space expansion, and shunt complications, only the increase in ventricular dimensions showed statistical significance ( $p < 0.001$ ) (Table 5).

Of the 45 patients, 16 underwent both preoperative and postoperative MMSE testing. The remaining 29 patients were lost to follow-up due to death, difficulties in transporting bedridden patients, and limited education. Among the 16 patients, significant MMSE improvement was observed in five patients, along with concurrent improvements in urinary incontinence and gait disturbance. However, Evans index values exhibited variability, increasing in some patients and decreasing in others. A statistically significant negative correlation was observed between patient age and preoperative MMSE scores ( $r = -0.593$ ;  $p < 0.001$ ), while no significant correlation was found between preoperative MMSE scores and complaint duration ( $r = 0.085$ ;  $p = 0.581$ ).

Although complete independence was not achieved in all cases, 40 patients experienced substantial benefits following shunting implantation. Of the five patients who did not benefit, one had Parkinson's disease and dementia, one had hypertension, diabetes, and bipolar disorder, one had anxiety disorder, one had cerebrovascular disease and

hypertension, and one had diabetes and coronary artery disease.

The comorbidities of patients, duration of symptoms, preoperative MMSE scores, and mortality rates were analyzed statistically. A significant correlation was observed between preoperative MMSE scores and both Alzheimer's disease and cerebrovascular disease. Additionally, the association between hypertension and mortality cases was statistically significant (Table 6 and Figures 1 and 2).

## DISCUSSION

The mechanism underlying NPH primarily involves CSF malabsorption at arachnoid granulations (5,6). Cases of iNPH have also been linked to periventricular ischemic events, weakening and expansion of the ventricular wall, and comorbid conditions such as hypertension, ischemic heart disease, diabetes, and high-density lipoprotein cholesterol (5). In our cohort, hypertension was the most common comorbidity, followed by diabetes, cerebrovascular disease, and coronary artery disease.

iNPH predominantly affects individuals aged 50-70 years (1). Previous studies reported prevalence rates of 3.3 per 100,000 among individuals aged 50-59 years, 49.3 per 100,000 among those aged 60-69 years, and 181.7 per 100,000 among those aged 70-79 years (7). The mean age of our patients was  $70.04 \pm 7.15$  years, with the youngest being 46 years old and the oldest 85 years old.

The classic symptom triad of iNPH includes gait disturbance, progressive dementia, and urinary incontinence. Gait disturbances were typically characterized by wide strides, shuffling, and magnetic movements, often accompanied by imbalance. Urinary incontinence, seen in 95% of cases, results from detrusor hyperactivity. Dementia symptoms manifest as psychomotor slowing, impaired attention, and

**Table 4.** Preoperative and postoperative Evans index and MMSE values of the patients

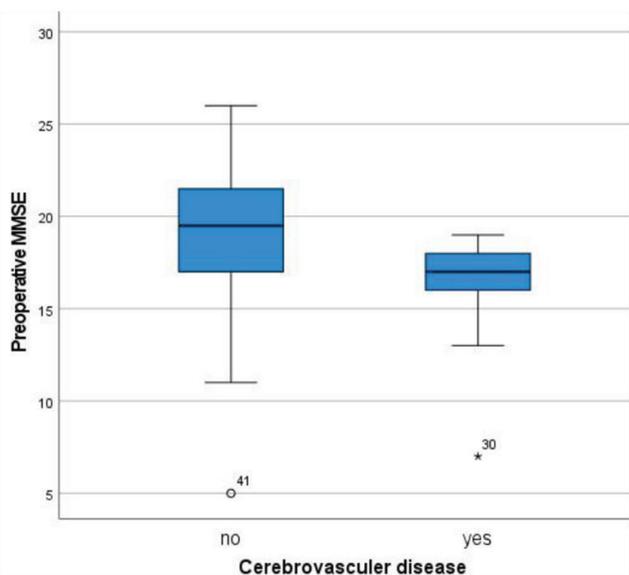
Variable	Preoperative	Postoperative	p-value
Evans index	0.34 (0.20-0.72)	0.34 (0.21-0.65)	0.821
MMSE	19.00 (5-26)	15.50 (7-26)	0.506

Data are presented as median (minimum-maximum) values  
MMSE: Mini-Mental State Examination

**Table 5.** Comparison of Evans index percentage change with postoperative improvements

Variable		Descriptive statistics	p-value
Improvement in walking	Yes	0.01 (-0.48-0.13)	0.280
	No	0.07 (-0.48-0.13)	
Improvement in urinary incontinence	Yes	0.01 (-0.48-0.13)	0.768
	No	0.00 (-0.46-0.27)	
Increase in the postoperative ventricular size	Yes	0.08 (0.01-0.27)	<0.001
	No	0.04 (-0.48-0.10)	
Enlargement of subarachnoid space (preoperative)	Yes	0.01 (-0.48-0.27)	0.866
	No+partially	0.01 (-0.14-0.13)	
Shunt complication	Yes	0.03 (-0.10-0.13)	0.732
	No	0.01 (-0.48-0.27)	

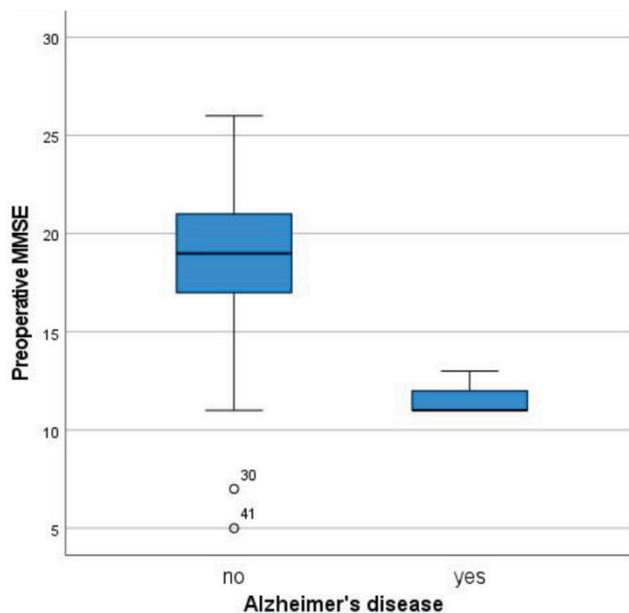
Data are presented as median (minimum-maximum) values



**Figure 1.** Comparison of preoperative MMSE and cerebrovascular disease

(Box plot of MMSE values for patients with and without CVD. Bold lines indicate medians, box plots show the 25<sup>th</sup> to 75<sup>th</sup> percentiles, bars indicate the 1.5-fold interquartile range, and circles represent values between the 1.5-fold and threefold interquartile range. Outliers are marked by asterisks)

MMSE: Mini-Mental State Examination, CVD: Cerebrovascular disease



**Figure 2.** Comparison of preoperative MMSE and Alzheimer's disease

(Box plot of MMSE values for patients with and without AD. Bold lines indicate medians, box plots show the 25<sup>th</sup> to 75<sup>th</sup> percentiles, bars indicate the 1.5-fold interquartile range, and circles represent values between the 1.5-fold and threefold interquartile range. Outliers are marked by asterisks)

MMSE: Mini-Mental State Examination, AD: Alzheimer's disease

executive and visuospatial dysfunction, even in patients with MMSE scores >25 (7). In our study, 80% of patients presented with the full triad, while others exhibited isolated or combined symptoms, including gait disturbance, imbalance, headache, and speech disturbance.

Differentiating iNPH from other causes of progressive dementia, such as atherosclerotic encephalopathy, is critical. Diagnostic approaches include radiological imaging, CSF flow dynamics analysis, neuropsychological assessments, and metabolic studies. Preoperative lumbar puncture (LP) to drain 50 cc of CSF is commonly used to evaluate symptom improvement before deciding on shunt surgery (5). In all our patients, CSF flow magnetic resonance imaging revealed hyperdynamic flow, and LP was performed to assess improvement in urinary incontinence and gait. MMSE and walking tests, conducted by neurology, confirmed the diagnosis, after which shunt surgery was performed.

It is hypothesized that in iNPH, problems in CSF circulation and absorption lead to decreased ventricular wall tensile strength and ventricular dilatation. These changes result in symptoms caused by periventricular tissue ischemia as well as tension and compression in neuronal connections (8). Normal values of the Evans index are reported as 0.20-0.25, with early or suspicious dilation classified as 0.25-0.30, and significant dilation defined as >0.30 (9). In cases of iNPH, the Evans index should be greater than 0.3, with no lesions obstructing CSF flow (5). Moreover, the Evans index has been shown to vary with age and gender, and postoperative changes in the Evans index are not associated with cognitive outcomes (9).

In our study, the preoperative Evans index was 0.34 (range: 0.20-0.72), while the postoperative Evans index remained at 0.34 (range: 0.21-0.65). No significant differences were observed in the preoperative and postoperative statistical evaluations ( $p=0.821$ ). A decrease in the Evans index was observed in 20 of the 45 patients, whereas an increase was noted in 25 patients. Among the 25 patients with an increased Evans index, 21 showed improved walking, and 13 exhibited improved urinary incontinence. These findings suggest that an increased Evans index may not correlate with clinical benefits, as reported in previous studies. Notably, when comparing postoperative Evans indices with other parameters, a significant association was observed only with increased postoperative ventricular dimensions ( $p<0.001$ ) (Table 6).

The most commonly used shunt types in iNPH treatment include VP, LP, and ventriculoatrial (VA) shunts. A study comparing VP and VA shunts found no significant difference in complication rates between the two groups in a cohort of 128

**Table 6.** Comorbidities of patients

Comorbidity	Variable	Yes	No	p-value
Parkinson's disease	Complaint period*	12 (12-12)	12 (6-48)	0.724
	Preop MMSE*	17 (11-19)	19 (5-26)	0.155
	Exitus†	2 (13.3)	13 (86.7)	0.591
Dementia	Complaint period*	12 (8-24)	12 (6-48)	0.781
	Preop MMSE*	17 (5-24)	19 (7-26)	0.214
	Exitus†	2 (13.3)	13 (86.7)	1.000
Epilepsy	Complaint period*	12 (12-24)	12 (6-48)	0.562
	Preop MMSE*	17 (7-21)	19 (5-26)	0.360
	Exitus†	1 (6.7)	14 (93.3)	1.000
Cognitive disorders	Complaint period*	—	12 (6-48)	—
	Preop MMSE*	—	19 (5-26)	—
	Exitus†	—	15 (100)	0.545
Cerebrovascular disease	Complaint period*	12 (6-24)	12 (6-48)	0.582
	Preop MMSE*	17 (7-19)	19.5 (5-26)	0.019
	Exitus†	2 (13.3)	13 (86.7)	0.695
Hypertension	Complaint period*	12 (6-48)	12 (6-36)	0.205
	Preop MMSE*	19 (5-24)	18 (7-26)	0.837
	Exitus†	8 (53.3)	7 (46.7)	0.044
Diabetes	Complaint period*	12 (6-24)	12 (6-48)	0.522
	Preop MMSE*	19 (5-24)	19 (7-26)	0.887
	Exitus†	7 (46.7)	8 (53.3)	0.070
Bipolar disorder	Complaint period*	—	12 (6-48)	—
	Preop MMSE*	—	19 (5-26)	—
	Exitus†	1 (6.7)	14 (93.3)	1.000
Anxiety disorder	Complaint period*	12 (8-12)	12 (6-48)	0.338
	Preop MMSE*	24 (17-24)	19 (5-26)	0.143
	Exitus†	2 (13.3)	13 (86.7)	0.254
Coronary artery disorder	Complaint period*	9 (6-48)	12 (6-36)	0.048
	Preop MMSE*	18 (13-23)	19 (5-26)	0.654
	Exitus†	4 (26.7)	11 (73.3)	0.410
Depression	Complaint period*	12 (12-24)	12 (6-48)	0.562
	Preop MMSE*	13 (7-18)	19 (5-26)	0.061
	Exitus†	—	15 (100)	0.540
Alzheimer's disease	Complaint period*	12 (6-24)	12 (6-48)	0.782
	Preop MMSE*	11 (11-13)	19 (5-26)	0.014
	Exitus†	1 (6.7)	14 (93.3)	1.000

\*: Median (minimum-maximum), †: n (%) values, MMSE: Mini-Mental State Examination

patients (10,11). Programmable valves are frequently preferred in iNPH patients due to their ability to allow intraventricular pressure adjustments, which reduce low drainage-related complications. Shunt pressure adjustments are reported to be necessary in 40% of cases (12). In our study, we used programmable VP shunts in all patients. Postoperative complications were observed in six (13.3%) patients, with four

(66.7%) requiring shunt revision due to subdural hemorrhage and two due to shunt dysfunction. The initial shunt pressure for patients who developed subdural hemorrhage was set at 110 mmH<sub>2</sub>O. To mitigate this risk, we increased the initial shunt pressure to 130 mmH<sub>2</sub>O in subsequent patients (n=5). Following this adjustment, no further cases of subdural hemorrhage were reported.

A review of the literature suggests that the use of valves designed to prevent excessive drainage is advisable to reduce complications such as subdural hemorrhage, headaches, and valve revisions (13). However, no consensus exists regarding the optimal shunt pressure. In our clinic, we employ a differential shunt system, and recommend an initial pressure of 130 mmH<sub>2</sub>O, although larger studies are needed to confirm this approach.

In a previous study, improvement rates among 179 NPH patients assessed at 3, 6, and 24 months post-shunt surgery were 33%, 60%, and 75%, respectively. Walking improved in 93% of patients, whereas improvements in dementia and incontinence were approximately half as frequent (6). In our cohort, 40 out of 45 (88.9%) patients experienced significant clinical benefits, predominantly in walking function. Specifically, 40 (88.9%) patients demonstrated improved gait, and 22 (48.9%) patients exhibited improvements in urinary incontinence. Patients also reported enhanced communication with relatives. Among the five patients who did not benefit from shunting, comorbidities such as Parkinson's disease, dementia, hypertension, diabetes, bipolar disorder, anxiety disorders, cerebrovascular disease, and coronary artery disease were identified as contributing factors.

In this study, MMSE was conducted preoperatively and at 3 months, 1 year, and 2 years postoperatively. The mean MMSE score increased from 22.4±5.4 preoperatively to 23.8±5.0 (p=0.0002) at 3 months and 23.7±4.8 (p=0.004) at 1 year postoperatively, before declining to 22.6±5.3 at 2 years. In our cohort, all 45 patients underwent preoperative MMSE testing; however, only 16 completed both preoperative and postoperative evaluations. The remaining 29 patients were lost to follow-up due to the challenges of transporting bedridden patients, mortality, or low educational levels. Among the 16 patients with complete MMSE data, no significant difference was observed between preoperative (median: 19.00; range: 5-26) and postoperative scores (median: 15.50; range: 7-26). However, five patients with significant increases in MMSE scores also showed improvements in urinary incontinence and gait disturbances. Low MMSE scores in our cohort may be attributable to delayed postoperative assessments, low educational levels, and high rates of comorbidities. A negative correlation was found between patient age and preoperative MMSE scores (r=-0.593; p<0.001), while no significant correlation was observed between preoperative MMSE scores and symptom duration (r=0.085; p=0.581).

Given the advanced age and high comorbidity burden in NPH patients, mortality is often unrelated to the disease

itself. In the literature, mortality rates of 37% and 13% have been reported (14,15). In our study, 15 (33.3%) out of 45 patients died during follow-up, with none of these deaths attributed to shunt-related complications. Mortality was due to underlying comorbidities.

### Study Limitations

This study has some limitations. Because the study was retrospective and single-center, it may not be representative of the broader patient population. We believe that multicenter studies with a larger number of patients would be necessary to reach more detailed results.

## CONCLUSION

The diagnosis and management of iNPH are complex processes requiring multidisciplinary collaboration between neurology and neurosurgery teams. The advanced age and comorbidities of these patients increase both surgical and postoperative risks. Our findings emphasize the importance of clinical evaluation in diagnosing iNPH, the limited utility of the Evans index in postoperative follow-up, and the significance of MMSE scores in both diagnosis and long-term monitoring. Despite the challenges, accurate diagnosis and appropriate treatment can significantly improve patients' quality of life.

### ETHICS

**Ethics Committee Approval:** The study was approved by the Ethics Committee of University of Health Sciences Türkiye, Bursa High Specialization Training and Research Hospital (approval no: 2024-TBEK 2024/06-01, date: 12.06.2024).

**Informed Consent:** Written informed consent was obtained from all participants or their legal guardians.

### FOOTNOTES

#### Authorship Contributions

Surgical and Medical Practices: E.B.G., Concept: E.B.G., A.A., Design: E.B.G., A.A., Data Collection or Processing: E.B.G., Analysis or Interpretation: E.B.G., A.A., Literature Search: E.B.G., A.A., Writing: E.B.G., A.A.

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## REFERENCES

1. Hakim S, Adams RD. The special clinical problem of symptomatic hydrocephalus with normal cerebrospinal fluid pressure: observations on cerebrospinal fluid hydrodynamics. *J Neurol Sci.* 1965;2:307-27.

2. Wallenstein MB, McKhann GM 2nd. Salomón Hakim and the discovery of normal-pressure hydrocephalus. *Neurosurgery*. 2010;67:155-9.
3. Jaraj D, Rabiei K, Marlow T, Jensen C, Skoog I, Wikkelsø C. Prevalence of idiopathic normal-pressure hydrocephalus. *Neurology*. 2014;82:1449-54.
4. Nakajima M, Yamada S, Miyajima M, Ishii K, Kuriyama N, Kazui H, et al. Guidelines for management of idiopathic normal pressure hydrocephalus (third edition): endorsed by the Japanese society of normal pressure hydrocephalus. *Neurol Med Chir (Tokyo)*. 2021;61:63-97.
5. Taşkın MM. Normal basınçlı hidrosefali: yeni kavramlar [Internet]. *Düşünen Adam*; 2008;21:45-58.
6. McGirl MJ, Woodworth G, Coon AL, Thomas G, Williams MA, Rigamonti D. Diagnosis, treatment, and analysis of long-term outcomes in idiopathic normal-pressure hydrocephalus. *Neurosurgery*. 2005;57:699-705.
7. Shprecher D, Schwalb J, Kurlan R. Normal pressure hydrocephalus: diagnosis and treatment. *Curr Neurol Neurosci Rep*. 2008;8:371.
8. Yılmaz MB. İdiopatik normal basınçlı hidrosefali hastalarında kraniyal MR bulguları. *Akd Med J*. 2019;5:194-200.
9. Zhou X, Xia J. Application of the Evans index in normal pressure hydrocephalus patients: a mini-review. *Front Aging Neurosci*. 2022;13:783092.
10. Lam CH, Villemure JG. Comparison between ventriculoatrial and ventriculoperitoneal shunting in the adult population. *Br J Neurosurg*. 1997;11:43-8.
11. Özdöl Ç, Belen D. Idiopathic normal pressure hydrocephalus. *Türk Nöroşirürji Derg*. 2009;19:97-104.
12. Grasso G, Torregrossa F, Leone L, Frisella A, Landi A. Long-term efficacy of shunt therapy in idiopathic normal pressure hydrocephalus. *World Neurosurg*. 2019;129:458-63.
13. Zipfel J, Kohlmann-Dell'Acqua C, Noell S, Trakolis L. 17 years of experience with shunt systems in normal pressure hydrocephalus— from differential pressure to gravitational valves. *World Neurosurg*. 2024;22:100293.
14. Kambara A, Kajimoto Y, Yagi R, Ikeda N, Furuse M, Nonoguchi N, et al. Long-term prognosis of cognitive function in patients with idiopathic normal pressure hydrocephalus after shunt surgery. *Front Aging Neurosci*. 2021;12:617150.
15. Kahlon B, Sjunnesson J, Rehnrona S. Long-term outcome in patients with suspected normal pressure hydrocephalus. *Neurosurgery*. 2007;60:327-32.