Ann Med Res

Current issue list available at Ann Med Res

Annals of Medical Research

journal page: annalsmedres.org

Evaluation of postoperative complications and mortality predictors in adult patients undergoing ventriculoperitoneal shunt surgery: A retrospective single-center study

Tamer Tamdogan [a], Ilke Tamdogan [b,*], Sevim Ondul [a]

[a] Giresun University, Faculty of Medicine, Department of Neurosurgery, Giresun, Türkiye
[b] Giresun University, Faculty of Medicine, Department of Anesthesiology and Reanimation, Giresun, Türkiye
*Corresponding author: drilkeipek@gmail.com (Ilke Tamdogan)

MAIN POINTS

- Programmable valve systems were associated with significantly lower mortality rates compared to standard valves in adult VPS patients.
- Hydrocephalus due to intracranial hemorrhage demonstrated a near-significant association with increased mortality, highlighting the need for targeted follow-up.
- Both early and late complication rates were 13.6%, with overdrainage and shunt infection being the most common, respectively.
- The study supports programmable shunt use and individualized patient monitoring to improve outcomes in high-risk hydrocephalus cases.

Cite this article as: Tamdogan T, Tamdogan I, Ondul S. Evaluation of postoperative complications and mortality predictors in adult patients undergoing ventriculoperitoneal shunt surgery: A retrospective single-center study. *Ann Med Res*. 2025;32(12):560--565. doi: 10.5455/annalsmedres.2025.06.145.

ABSTRACT

Aim: The aim of our study is to retrospectively analyze the incidence of postoperative complications in adult patients who underwent ventriculoperitoneal shunt (VPS) surgery for hydrocephalus and to identify clinical, demographic, and surgical predictors of mortality.

Materials and Methods: This is a single-center retrospective analysis including 44 patients aged 18 years and older who underwent primary or revision VPS surgery between September 2021 and January 2025. Data including demographic characteristics, comorbidities, hydrocephalus etiology, type of shunt (programmable vs. standard), clinical presentation, early and late complications, and mortality were collected and analyzed. Statistical analysis involved independent t-tests and chi-square or Fisher's exact tests as appropriate.

Results: The mean patient age was 68.8 ± 10.8 years, with a mortality rate of 29.5% observed during follow-up. Early and late complication rates were each 13.6%. Over-drainage (9.1%) was the most common early complication, while shunt infection (6.8%) predominated among late complications. Mortality was significantly higher in patients with standard valves (61.5%) compared to those with programmable valves (38.5%, p<0.001). Hydrocephalus secondary to intracranial hemorrhage was associated the highest rate and it was slightly above the significance level (30.8%, p=0.053).

Conclusion: The type of shunt system and hydrocephalus etiology, particularly intracranial hemorrhage, were identified as the most significant predictors of mortality. The use of programmable valve systems and close monitoring of high-risk patients may improve outcomes.

Keywords: Ventriculoperitoneal shunt, Hydrocephalus, Postoperative complications, Neurosurgery

Received: Jun 10, 2025 **Accepted:** Sep 29, 2025 **Available Online:** Dec 25, 2025

Copyright © 2025 The author(s) - Available online at annalsmedres.org. This is an Open Access article distributed under the terms of Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

INTRODUCTION

Hydrocephalus is a significant neurological disorder originating from the central nervous system. It may result from any pathology that affects the production, circulation, or absorption of cerebrospinal fluid (CSF). This condition may be linked to various etiologies, including intraventricular hemorrhage, congenital anomalies, brain tumors, infections such as meningitis, and head trauma. The main characteristics of hydrocephalus are pathological dilation of the ventricular system and subarachnoid space, potentially leading to substantial neurological sequelae due to increased intracranial pressure [1,2].

Currently, surgical interventions are the mainstay of the management of hydrocephalus, with ventriculoperitoneal shunt (VPS) placement being the most frequently employed technique. This procedure is designed to redirect cerebrospinal fluid (CSF) from the intraventricular space to the peritoneal cavity, thereby alleviating intracranial pressure. VPS is regarded as a life-saving intervention, particularly for patients who do not respond to conventional treatments or those ex-

periencing acute elevations in intracranial pressure. The literature indicates that shunt placement significantly reduces postoperative mortality rates [3,4]. However, despite the success of this surgical technique, the relatively high incidence of postoperative complications necessitates shunt revisions, resulting in considerable morbidity and increased hospital costs. Due to their invasive nature and external components, shunt systems are susceptible to various complications, including infections, mechanical obstructions, over-drainage, shunt migration, and peritoneal complications [5-7]. Various studies have reported complication rates of up to 30–40% associated with shunt systems [8].

These complications not only contribute to surgical failure but also adversely affect clinical prognosis by increasing hospital readmission rates, prolonging ICU stays, and elevating healthcare costs [9]. Repeated shunt revisions, in addition to imposing a financial burden on the healthcare system, significantly impact the psychosocial well-being of patients [10]. The primary objective of this study is to retrospectively ascertain the incidence of postoperative complications in adult patients undergoing VPS surgery and to analyze the potential effects of demographic, clinical, and surgical variables on mortality. The findings aim to contribute to the guide the strategies that may mitigate the risk of shunt-related complications and to provide guidance for clinical practices aimed at improving patient outcomes.

MATERIALS AND METHODS

This investigation constitutes a single-center retrospective analysis of patients who underwent ventriculoperitoneal shunt (VPS) surgery at our clinic. The study protocol was approved by the Ethics Committee of Giresun Training and Research Hospital (Ethics Committee Date/Approval Number: 28.05.2025/15) and was conducted in accordance with the ethical principles delineated in the Declaration of Helsinki. Given the retrospective nature of the study, informed consent was not obtained from the patients.

Study population

The study included patients who underwent VPS surgery at our clinic between September 2021 and January 2025. Inclusion criteria encompassed individuals aged ≥18 years, those who had undergone primary or revision VPS surgery, and those with complete medical records. Patients who received non-VPS hydrocephalus treatment or had incomplete clinical data were excluded from the study.

Data collection and evaluation

All data were retrospectively obtained using the hospital automation system and patient medical records. Recorded variables included demographic characteristics (age, sex), comorbid conditions, etiology of hydrocephalus (congenital, acquired, normal pressure, etc.), clinical presentation at admission, nature of the surgery (primary or revision), and type of shunt used (programmable or standard valve). Additionally, early (<30 days) and late (>30 days) shunt dysfunctions, mechanical complications (such as obstruction, fracture, or migration of the shunt system), infectious complications (such as meningitis or peritonitis), and over-drainage-related pathologies (such as subdural hematoma or slit ventricle syndrome) were evaluated along with mortality rates. All data were recorded in a standardized data collection form for analysis.

Statistical analysis

Descriptive statistics were reported as mean, standard deviation, median, minimum, and maximum values for continuous variables, and as frequency and percentage for categorical variables. The distribution of variables was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests. For normally distributed quantitative variables, mean values were compared using the independent samples t-test. For categorical independent variables, the chi-square test was employed. In cases where the assumptions of the chi-square test were not met, Fisher's exact test was applied. Statistical significance was set at $p < 0.05$. All statistical analyses were conducted using IBM SPSS Statistics version 28.0 (Armonk, NY: IBM Corp.). A post hoc power analysis for the mortality–shunt type association (χ^2 test, df = 1; $\alpha = 0.05$; N = 44; group proportions 20.5% vs. 79.5%; assumed effect size w = 0.50) using G*Power 3.1.9.4 yielded an achieved power of 0.91.

RESULTS

A total of 44 patients participated in the study. The mean age was 68.8 ± 10.8 years, with a median age of 69.5 years. In terms of gender distribution, 54.5% (n=24) of the patients were male, while 45.5% (n=20) were female. Comorbidities were present in the 95.5%of cases. The most prevalent comorbidities included hypertension (84.1%), coronary artery disease (27.3%), diabetes mellitus (20.5%), Alzheimer's disease (15.9%), and other systemic disorders (50.0%) (Table 1). Regarding the type of hydrocephalus, 81.8% of the cases were diagnosed with communicating hydrocephalus, and 18.2% with obstructive hydrocephalus. Hemorrhage was identified as the most common etiology (13.6%), followed by trauma (9.1%), tumors (6.8%), and infections (2.3%). The most frequently reported presenting symptoms were gait disturbances (81.8%), altered mental status (79.5%), and urinary incontinence (79.5%). Headache (34.1%) and nausea/vomiting (9.1%) were less commonly observed (Table 1). Programmable valves were utilized in 79.5% of patients, whereas standard valves were employed in 20.5%. Shunt revision was unnecessary in 90.9% of the patients; only four patients (9.1%) required a single revision. Additionally, five patients (11.4%) underwent external ventricular drainage (EVD) prior to shunt surgery (Table 1).

In the early postoperative period, the overall complication rate was observed to be 13.6%. The most prevalent com-

https://doi.org/10.5455/annalsmedres.2025.06.145

Table 1. Demographic data and clinical descriptors.

		Min-Max	Median	Mean ± SD	n	-	%
Age		44.0-93.0	69.5	68.8±10.8			
Gender	Female				20	-	45.5%
	Meal				24	-	54.5%
Comorbidities	No				2	-	4.5%
	Yes				42	-	95.5%
Hypertension (HT)					37	-	84.1%
Coronary artery disease					12	-	27.3%
Diabetes mellitus (DM)					9	-	20.5%
Alzheimer's disease					7	-	15.9%
Others					22	-	50.0%
Type of Hydrocephalus							
Communicative					36	-	81.8%
Obstructive					8	-	18.2%
	Post-traumatic				4	-	9.1%
	Infectious				1	-	2.3%
	Hemorrhagic				6	-	13.6%
	Tumor-related				3	-	6.8%
Presenting Symptoms	Gait disturbance				36	-	81.8%
	Altered mental status				35	-	79.5%
	Urinary incontinence				35	-	79.5%
	Headache				15	-	34.1%
	Nausea/Vomiting				4	-	9.1%
Shunt Type	Standard				9	-	20.5%
	Programmable				35	-	79.5%
Shunt Revision Performed					4	-	9.1%
External Ventricular Drain (EVD)					5	-	11.4%

Table 2. Complication and mortality rates.

		n	%
Early Complications	No	38	86.4%
	Yes	6	13.6%
	- Shunt Obstruction	1	2.3%
	- Overdrainage	4	9.1%
	- Shunt Infection	1	2.3%
Late Complications	No	38	86.4%
	Yes	6	13.6%
	- Shunt Obstruction	1	2.3%
	- Migration	1	2.3%
	- Overdrainage	1	2.3%
	- Shunt Infection	3	6.8%
Mortality Rate		13	29.5%

plication was over-drainage (9.1%), followed by shunt obstruction (2.3%) and shunt infection (2.3%) as other early complications. Late complications occurred at an equivalent rate (13.6%), with shunt infection being the most frequently observed (6.8%), followed by shunt migration (2.3%), overdrainage (2.3%), and shunt obstruction (2.3%). During the follow-up period, the mortality rate was determined to be 29.5% (13 patients) (Table 2). Mortality rates were significantly higher ($p < 0.05$) in patients with standard valves (Table 3).

Upon analyzing variables associated with mortality, a statistically significant difference was observed exclusively concerning the type of ventriculoperitoneal shunt (VPS) utilized. The mortality rate was notably lower among patients who received programmable shunts (38.5%), in contrast to those who received standard valve shunts, which exhibited a mortality rate of 61.5% ($p<0.001$) (Table 3). In the analysis based on the etiology of hydrocephalus, the mortality rate for patients with hemorrhagic hydrocephalus was 30.8%, approaching statistical significance ($p = 0.053$). Although the mortality rates for

https://doi.org/10.5455/annalsmedres.2025.06.145

Table 3. Variables associated with mortality.

		Mortality (-) (n:31)		Mortality (+) (n:13)		p
Age (Mean±SD)		67.4±10.4		72.2±11.2		0.179[t]
		n	%	n	%	
Gender	Female	16	51.6%	4	30.8%	0.205χ^2
	Male	15	48.4%	9	69.2%	
Comorbidities	No	1	3.2%	1	7.7%	0.508χ^2
	Yes	30	96.8%	12	92.3%	
Type of Hydrocephalus						
Communicative		27	87.1%	9	69.2%	0.161χ^2
Obstructive		4	12.9%	4	30.8%	
-Post-traumatic		1	3.2%	3	23.1%	0.071χ^2
-Infectious		0	0.0%	1	7.7%	0.295χ^2
-Hemorrhagic		2	6.5%	4	30.8%	0.053χ^2
-Tumor-related		1	3.2%	2	15.4%	0.204χ^2
Shunt Type	Standard	1	3.2%	8	61.5%	**<0.001**χ^2
	Programmable	30	96.8%	5	38.5%	
Early Complications	No	28	90.3%	10	76.9%	0.339χ^2
	Yes	3	9.7%	3	23.1%	
- Shunt Obstruction		0	0.0%	1	7.7%	0.295χ^2
- Migration		3	9.7%	1	7.7%	1.000χ^2
- Overdrainage		0	0.0%	1	7.7%	0.295χ^2
Late Complications	No	27	87.1%	11	84.6%	1.000χ^2
	Yes	4	12.9%	2	15.4%	
- Shunt Obstruction		1	3.2%	0	0.0%	1.000χ^2
- Migration		0	0.0%	1	7.7%	0.295χ^2
- Overdrainage		1	3.2%	0	0.0%	1.000χ^2
- Shunt Infection		2	6.5%	1	7.7%	1.000χ^2

[t] Independent samples t-test/ χ^2 Chi-square test (Fisher's exact test).

patients with trauma-related (23.1%) and tumor-related hydrocephalus (15.4%) were higher compared to other etiological causes, these differences did not achieve statistical significance (p = 0.071 and p = 0.204, respectively) (Table 3).

DISCUSSION

In this retrospective study, clinical findings, postoperative complications, and mortality rates were analyzed in adult patients who underwent VPS surgery for the treatment of hydrocephalus. While our findings are generally consistent with those reported in the literature, some results offer unique contributions.

The most frequently symptoms in our study were gait disturbances (81.8%), cognitive changes (79.5%), and urinary incontinence (79.5%), which are characteristic symptoms of normal pressure hydrocephalus (NPH). This supports the clinical presentation typically observed in elderly individuals with NPH [11]. Headache (34.1%) and nausea/vomiting (9.1%), which are signs of elevated intracranial pressure, were observed at lower rates. The lower frequency of these findings aligns with the predominance of communicating hydrocephalus (81.8%) in our cohort. In cases where the clinical condition deteriorated rapidly and hydrocephalus presented acutely, 11.4% of patients required external ventricular drainage (EVD). Given that NPH generally has an insidious onset and progresses slowly, delays in diagnosis are common and may contribute to increased neurological damage. Therefore, early recognition of these characteristic symptoms is crucial, especially in individuals at risk [12].

Complications associated with shunt surgery continue to pose significant challenges in the management of hydrocephalus. In our study, the overall incidence of both early and late complications was determined to be 13.6%, aligning with the 10–30% range documented in existing literature. The presence of complications during both early and late stages underscores the importance of long-term follow-up. In a systematic review of 28 studies published between 2006 and 2010, Toma et al. [13] reported a surgical complication rate of 8.2%. Moreover, multicenter prospective cohort studies have documented serious complication rates ranging from 15% to 22% [14,15]. Standardization of surgical techniques, appropriate selection of shunt materials, and improvement of postoperative monitoring protocols are critical to reducing complication rates.

Shunt infection remains a prevalent and serious complication associated with shunt surgery. Infection rates in the pediatric population are typically reported to range from 5% to 15%, whereas in adult patients, this rate varies between 3%

https://doi.org/10.5455/annalsmedres.2025.06.145

and 10% [4,7,16]. Although the rates are technically lower in adults, they are influenced by factors such as immune status, the materials used, antibiotic prophylaxis, and revision surgery [13,17]. In our study, the early shunt infection rate was 2.3%, while the late infection rate was 6.8%. This finding suggests that infections are not confined to the perioperative period and pose a significant risk even during long-term follow-up. The disparity between early and late infection rates indicates that the etiology of infections may evolve over time, necessitating the optimization of late follow-up protocols.

The most prevalent early complication identified was over-drainage (9.1%), commonly attributed to the siphon effect, inappropriate selection of valve systems, or inadequate personalization of valve pressure settings. The literature indicates that over-drainage is more frequently observed in the early postoperative period [13,18]. In standard valve systems, the inability to adjust pressure heightens the risk of complications. Conversely, programmable valve systems are specifically engineered to mitigate over-drainage. Despite the extensive use of programmable shunts in our study, early over-drainage (9.1%) was still more prevalent than in the later period (2.3%). This may be attributed to the challenges in determining the optimal valve pressure for the patient during the initial stages. Factors such as the patient's age, cerebrospinal fluid (CSF) production rate, body position, and type of hydrocephalus can influence the ideal valve pressure. This suggests that, notwithstanding the theoretical advantages of programmable shunts, identifying the most appropriate valve pressure for the patient may necessitate time. The literature suggests that the effectiveness of programmable systems in reducing complications becomes more apparent once optimal pressure settings are achieved [19,20].

In our study, the overall mortality rate was 29.5%, and a statistically significant association was observed between shunt type and mortality ($p = .000$). Specifically, the mortality rate was 38.5% among patients with programmable shunts, compared to 61.5% in those with standard valve systems. This finding indicates that programmable systems may be more effective in regulating intracranial pressure, thereby preventing complications and enhancing overall survival. The literature contains a limited number of studies that directly compare mortality rates between programmable and standard shunt systems. In a retrospective cohort study by Chen et al. [21] programmable and standard valves were compared in adult patients with various etiologies of hydrocephalus, revealing that programmable valve systems reduced the need for revision and mortality. Similarly, a study by McGirt et al. [22] conducted in pediatric hydrocephalus patients demonstrated that programmable valve systems reduced the risk of proximal shunt obstruction and revision rates compared to standard systems, although mortality rates were not directly assessed.

Consequently, it can be inferred that programmable valve systems may reduce mortality indirectly by decreasing complication rates and the need for revision. Thus, the implementation of programmable valve systems in high-risk patient groups may represent a significant treatment strategy for improving clinical outcomes.

On the other hand, although the mortality rate was lower in the programmable shunt group in our study, the majority of deaths were found to be unrelated to direct shunt-related complications. Among the 13 patients who died, 3 cases were due to sepsis, 2 to multiple trauma, 1 to massive intracranial hemorrhage, and 1 to malignant brain tumor. In the remaining 6 patients, death occurred due to deterioration in general condition following shunt surgery, primarily attributed to advanced age and pre-existing cardiovascular/metabolic comorbidities. This finding suggests that mortality is not solely influenced by surgical complications but is also significantly affected by the patients' systemic health status and coexisting medical conditions.

In the assessment of etiological factors, mortality approached statistical significance in instances of hydrocephalus secondary to intracranial hemorrhage (30.8%, $p = 0.053$). This finding indicates that hemorrhage-related hydrocephalus is associated with a poorer prognosis, necessitating closer monitoring and individualized treatment strategies for these patients. Corroborating this, a comprehensive database analysis by Nadel et al. [23] also identified significantly elevated mortality rates in cases of hydrocephalus following hemorrhage. Although early and late complications did not exhibit a statistically significant association with mortality, the early complication rate was notably higher among patients who succumbed (23.1% vs. 9.7%), which is clinically significant. The literature suggests that early postoperative complications, particularly infections and drainage-related issues, may adversely affect long-term prognosis [4,16].

Limitations

The limitations of this study include its single-center, retrospective design and relatively small sample size. Additionally, variations in surgical techniques, practitioner experience, and details regarding antibiotic prophylaxis, which may contribute to shunt failure, were not uniformly documented across all patients. Nevertheless, our findings offer original contributions that may inform future large-scale, prospective studies.

CONCLUSION

In conclusion, our study identified shunt type and the etiology of hydrocephalus, particularly intracranial hemorrhage, as the variables exerting the most significant impact on mortality. The adoption of programmable valve systems and the implementation of a multidisciplinary approach for closer monitoring of patients with bleeding etiology emerge as crucial strategies to mitigate mortality rates.

This study underscores that complication rates following VPS surgery remain a significant clinical concern and that certain

https://doi.org/10.5455/annalsmedres.2025.06.145

modifiable factors, particularly shunt type, influence mortality. Based on the data obtained, it is posited that the use of a programmable valve system may be advantageous in reducing complication rates, especially in adult patients with advanced age and comorbidities. In cases of hydrocephalus secondary to intracranial hemorrhage, structured follow-up protocols should be developed to facilitate closer clinical monitoring and early intervention. Multicenter, prospective studies with larger sample sizes in this domain will enhance the generalizability of the data obtained and provide more robust evidence for clinical practice.

Ethics Committee Approval: The study protocol was approved by the Ethics Committee of Giresun Training and Research Hospital (Ethics Committee Date/Approval Number: 28.05.2025/15).

Informed Consent: Informed consent was not obtained due to the retrospective design of the study.

Peer-review: Externally peer-reviewed.

Conflict of Interest: The authors declare no competing interests.

Author Contributions: Conception: TT, İT, SO; Design: TT, İT, SO; Supervision: TT, İT, SO; Materials: TT, İT, SO; Data Collection and/or Processing: TT, İT, SO; Analysis and/or Interpretatio: TT, İT, SO; Literature Review: TT, İT, SO; Writing: TT, İT, SO; Critical Review: TT, İT, SO.

Financial Disclosure: The authors received no financial assistance for this paper's research, authorship, or publishing.

REFERENCES

1. Smith M. Refractory Intracranial Hypertension: The Role of Decompressive Craniectomy. *Anesth Analg*. 2017;125(6):1999-2008. doi: 10.1213/ANE.0000000000002399.
2. Wang QP, Ma JP, Zhou ZM, et al. Hydrocephalus after decompressive craniectomy for malignant hemispheric cerebral infarction. *Int J Neurosci*. 2016;126(8):707-712. doi: 10.3109/00207454.2015.1055357.
3. Hanna RS, Essa AA, Makhlouf GA, et al. Comparative Study Between Laparoscopic and Open Techniques for Insertion of Ventriculperitoneal Shunt for Treatment of Congenital Hydrocephalus. *J Laparoendosc Adv Surg Tech A*. 2019;29(1):109-113. doi: 10.1089/lap.2017.0594.
4. Erps A, Roth J, Constantini S, et al. Risk factors and epidemiology of pediatric ventriculoperitoneal shunt infection. *Pediatr Int*. 2018;60(12):1056-1061. doi: 10.1111/ped.13709.
5. Kutty RK, Sreemathyamma SB, Korde P, et al. Outcome of Ventriculosubgaleal Shunt in the Management of Infectious and Non-infectious Hydrocephalus in Pre-term Infants. *J Pediatr Neurosci*. 2018;13(3):322-328. doi: 10.4103/JPN.JPN_41_18.
6. Kestle J, Drake J, Milner R, et al. Long-term follow-up data from the Shunt Design Trial. *Pediatr Neurosurg*. 2000;33(5):230-236. doi: 10.1159/000055960.
7. Simon TD, Hall M, Riva-Cambrin J, et al. Infection rates following initial cerebrospinal fluid shunt placement across pediatric hospitals in the United States. Clinical article. *J Neurosurg Pediatr*. 2009;4(2):156-165. doi: 10.3171/2009.3.PEDS08215.
8. Drake JM, Kestle JR, Milner R, et al. Randomized trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus. *Neurosurgery*. 1998;43(2):294-305. doi: 10.1097/00006123-199808000-00068.
9. Tuli S, Drake J, Lawless J, et al. Risk factors for repeated cerebrospinal shunt failures in pediatric patients with hydrocephalus. *J Neurosurg*. 2000;92(1):31-38. doi: 10.3171/jns.2000.92.1.0031.10.3171/jns.2000.92.1.0031
10. Isaacs AM, Riva-Cambrin J, Yavin D, et al. Age-specific global epidemiology of hydrocephalus: Systematic review, metanalysis and global birth surveillance [published correction appears in *PLoS One*. 2019 Jan 10;14(1):e0210851. doi: 10.1371/journal.pone.0210851.]. *PLoS One*. 2018;13(10):e0204926. doi: 10.1371/journal.pone.0204926.
11. Relkin N, Marmarou A, Klinge P, et al. Diagnosing idiopathic normal-pressure hydrocephalus. *Neurosurgery*. 2005;57(3Suppl):S4-16. doi: 10.1227/01.neu.0000168185.29659.c5.
12. Petersen J, Hellström P, Wikkelsø C, et al. Improvement in social function and health-related quality of life after shunt surgery for idiopathic normal-pressure hydrocephalus. *J Neurosurg*. 2014;121(4):776-784. doi: 10.3171/2014.6.JNS132003.
13. Toma AK, Papadopoulos MC, Stapleton S, et al. Systematic review of the outcome of shunt surgery in idiopathic normal-pressure hydrocephalus. *Acta Neurochir (Wien)*. 2013;155(10):1977-1980. doi: 10.1007/s00701-013-1835-5.
14. Saehle T, Farahmand D, Eide PK, et al. A randomized controlled dual-center trial on shunt complications in idiopathic normal-pressure hydrocephalus treated with gradually reduced or "fixed" pressure valve settings. *J Neurosurg*. 2014;121:1257–63. doi: 10.3171/2014.7.JNS14283.
15. Miyajima M, Kazui H, Mori E, et al. One-year outcome in patients with idiopathic normal-pressure hydrocephalus: comparison of lumboperitoneal shunt to ventriculoperitoneal shunt. *J Neurosurg*. (2016) 125:1483–92. doi: 10.3171/2015.10.JNS151894.
16. Riva-Cambrin J, Kestle JR, Holubkov R, et al. Risk factors for shunt malfunction in pediatric hydrocephalus: a multicenter prospective cohort study. *J Neurosurg Pediatr*. 2016;17(4):382-390. doi: 10.3171/2015.6.PEDS14670.
17. Kim M, Choi JH, Park JC, et al. Ventriculoperitoneal shunt infection and malfunction in adult patients: incidence, risk factors, and long-term follow-up of single institution experience. *Neurosurg Rev*. 2024;47(1):269. doi: 10.1007/s10143-024-02505-x.
18. Bozhkov Y, Roessler K, Hore N, et al. Neurological outcome and frequency of overdrainage in normal pressure hydrocephalus directly correlates with implanted ventriculo-peritoneal shunt valve type. *Neurol Res*. 2017;39(7):601-605. doi: 10.1080/01616412.2017.1321300.
19. Ros B, Iglesias S, Linares J, et al Shunt Overdrainage: Reappraisal of the Syndrome and Proposal for an Integrative Model. *J Clin Med*. 2021;10(16):3620. doi: 10.3390/jcm10163620.
20. Yamada S, Ishikawa M, Nakajima M, et al. Reconsidering Ventriculoperitoneal Shunt Surgery and Postoperative Shunt Valve Pressure Adjustment: Our Approaches Learned From Past Challenges and Failures. *Front Neurol*. 2022;12:798488. doi: 10.3389/fneur.2021.798488.
21. Chen KH, Hsu PW, Wu BC, et al. Long-term follow-up and comparison of programmable and non-programmable ventricular cerebrospinal fluid shunts among adult patients with different hydrocephalus etiologies: a retrospective cohort study. *Acta Neurochir (Wien)*. 2023;165(9):2551-2560. doi: 10.1007/s00701-023-05734-z.
22. McGirt MJ, Buck DW, Sciubba D, et al. Adjustable vs set-pressure valves decrease the risk of proximal shunt obstruction in the treatment of pediatric hydrocephalus. *Childs Nerv Syst*. 2007;23(3):289-295. doi: 10.1007/s00381-006-0226-0.
23. Nadel JL, Wilkinson DA, Linzey JR, et al. Thirty-Day Hospital Readmission and Surgical Complication Rates for Shunting in Normal Pressure Hydrocephalus: A Large National Database Analysis. *Neurosurgery*. 2020;86(6):843-850. doi: 10.1093/neuros/nyz299.

https://doi.org/10.5455/annalsmedres.2025.06.145