

Research Article

Five-Year Retrospective Cohort Study of Hydrocephalus Incidence and Patient Outcomes in Yogyakarta

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Abstract

Hydrocephalus is characterized by abnormal cerebrospinal fluid (CSF) accumulation in the brain's ventricles, which can lead to significant morbidity and mortality without timely intervention. This retrospective cohort study aimed to evaluate the incidence, survival outcomes, and risk factors associated with hydrocephalus among patients treated at Bethesda Hospital Yogyakarta over a five-year period. Medical records of 203 patients diagnosed with hydrocephalus between 2019 and 2024 were reviewed, and patient demographics, hydrocephalus type, treatment modality, and comorbidities—assessed using the Charlson Comorbidity Index—were analyzed. Survival outcomes were examined using Kaplan-Meier analysis, and hazard ratios (HR) were calculated via Cox regression. Most patients were aged ≥ 60 years (60%) and male (53.2%), with non-communicating hydrocephalus being the most common type (43.8%). Infants (<1 year) demonstrated the highest five-year survival rate (100%), while patients aged 41–59 had the lowest (57.1%; HR: 13.8, $p = 0.018$). Surgical treatment, predominantly ventriculoperitoneal shunting, significantly improved survival (74.0%) compared with conservative management (60.2%; HR: 1.649, $p = 0.05$). Among hydrocephalus types, ex-vacuo presented the best prognosis (100% survival), whereas non-communicating hydrocephalus had the poorest (63.7%; HR: 14.4, $p = 0.016$). Higher comorbidity scores were associated with worse outcomes, particularly in acquired cases. Overall, hydrocephalus outcomes varied significantly by age, type, comorbidities, and treatment approach, with surgical intervention offering a clear survival advantage and reinforcing its role as the primary management strategy. Early diagnosis and personalized treatment planning are crucial to improving long-term outcomes in hydrocephalus patients.

Keywords

Hydrocephalus, Retrospective Cohort Study, Survival Analysis, Ventriculoperitoneal Shunt, Kaplan-Meier Estimator, Comorbidities, Patient Outcomes

1. Introduction

Background and Rationale

Hydrocephalus is a neurological condition characterized by abnormal accumulation of cerebrospinal fluid (CSF) within the brain's ventricular system, which can occur with or

without increased intracranial pressure. In cases where intracranial pressure remains normal, ventricular enlargement may result from cerebral atrophy or compensatory dilation [1]. The most common treatment is the surgical insertion of a ven-

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tricoloperitoneal shunt (VPS), which diverts CSF from the brain to the peritoneal cavity for reabsorption. While VPS significantly improves clinical outcomes, it remains associated with high complication rates, including infections and mechanical malfunctions, often necessitating multiple revisions. Although recent advancements—such as programmable valves and antibiotic-impregnated shunts—have reduced these risks, repeated surgeries have been linked to cognitive deterioration and diminished quality of life [2].

The incidence, prognosis, and optimal treatment strategies for hydrocephalus vary significantly across age groups, underlying etiologies, and the presence of comorbid conditions [3]. However, data on long-term outcomes and prognostic indicators for hydrocephalus patients in Indonesia remain scarce. Local insights are essential to guide context-specific clinical decisions, particularly in tertiary care settings with limited resources.

Objectives

This study aims to evaluate the five-year incidence and survival outcomes of patients diagnosed with hydrocephalus at Bethesda Hospital Yogyakarta. It specifically seeks to analyze the demographic and clinical characteristics of these patients, including age, sex, and hydrocephalus type; compare survival outcomes between surgical and conservative treatment approaches; assess the impact of comorbidities—measured using the Charlson Comorbidity Index (CCI)—on patient prognosis; and identify key prognostic factors associated with improved or worsened outcomes in hydrocephalus management. The prespecified hypothesis is that surgical intervention is associated with better long-term survival compared to conservative treatment and that the presence and severity of comorbidities significantly influence survival outcomes.

2. Methods

2.1. Study Design

This study employed a retrospective cohort design, analyzing patient data collected over a five-year period to evaluate the incidence, clinical characteristics, and survival outcomes of hydrocephalus.

2.2. Setting

The study was conducted at Bethesda Hospital, a tertiary referral center in Yogyakarta, Indonesia, using medical records from January 1, 2019 to December 31, 2024. Data collection and analysis took place in 2024 following ethical approval from the hospital's Ethics and Research Committee (Reference: 43/KEPK-RSB/VIII/24).

2.3. Participants

Patients were eligible if they had a confirmed diagnosis of

hydrocephalus, established through clinical features and neuroimaging, and were treated at Bethesda Hospital during the study period. Inclusion criteria were (1) a confirmed diagnosis by neurology or neurosurgery specialists and (2) complete medical records. Exclusion criteria included patients with incomplete data or those managed entirely outside the institution. No matching was applied in this study (Item 6b not applicable). Follow-up was based on recorded survival status through the end of the study or until death, with outcomes censored for patients lost to follow-up or alive at the study's conclusion.

2.4. Variables

The primary outcome of this study was overall survival, defined as the time from the initiation of hydrocephalus treatment to death or the last known follow-up. Key exposures and predictors included age group (<1 year, 1–17 years, 18–40 years, 41–59 years, and ≥60 years), sex, and hydrocephalus classification, which was categorized into communicating (non-obstructive), non-communicating (obstructive), normotensive (normal pressure hydrocephalus/NPH), ex-vacuo, acquired (post-infectious or post-traumatic), and congenital types. Treatment modality was classified as operative—comprising ventriculoperitoneal shunt (VPS) or external ventricular drainage (EVD)—versus non-operative supportive or conservative management. Comorbidities were systematically assessed using the Charlson Comorbidity Index (CCI), which assigns weighted scores to 17 predefined medical conditions based on their association with long-term mortality risk. Each condition carries a weight from 1 to 6 (e.g., myocardial infarction, diabetes without complications, and chronic pulmonary disease are weighted as 1; moderate or severe liver disease is weighted as 3; metastatic solid tumors and AIDS are weighted as 6). The individual weights were summed to obtain a total comorbidity score for each patient. To facilitate analysis, patients were categorized into four groups: none (CCI = 0), mild (CCI = 1–2), moderate (CCI = 3–4), and severe (CCI ≥ 5). This classification has been widely validated as a prognostic tool in surgical and oncological outcomes research, allowing standardized comparison across different patient populations.

Diagnostic confirmation of hydrocephalus was based on standard neuroimaging criteria. Ventriculomegaly was quantified using the Evans Index, defined as the ratio of the maximum width of the frontal horns of the lateral ventricles to the maximum inner diameter of the skull at the same level; a value >0.30 was considered diagnostic of hydrocephalus. In addition, the frontal horn ratio (ratio of the frontal horn width to the maximum anteroposterior diameter of the skull) and Gudeman's criteria were applied, which assess disproportionate enlargement of the ventricular system relative to cortical sulci, thereby distinguishing true hydrocephalus from cortical atrophy. Supportive radiological features such as periventricular lucency (suggestive of transependymal CSF

flow) and ballooning of the third ventricle were also noted when present.

For suspected normal pressure hydrocephalus (NPH), diagnosis required fulfillment of both clinical and imaging criteria. Clinically, the presence of at least one component of the classic triad—gait disturbance, cognitive decline, or urinary urgency/incontinence—was necessary. Imaging confirmation included ventriculomegaly as described above, often with disproportionately enlarged ventricles compared to sulcal atrophy. Other potential causes of ventriculomegaly (such as severe cerebral atrophy, space-occupying lesions, or prior extensive ischemic injury) were carefully excluded. Where available, ancillary tests such as CSF tap test or continuous intracranial pressure monitoring were considered to support the diagnosis.

2.5. Data Sources and Measurement

Data were extracted from hospital medical records by trained research personnel using a standardized form. Demographic data, clinical diagnosis, neuroimaging reports, comorbidity profiles, treatment type, and mortality status were recorded. All assessments were performed within the same institution, ensuring comparability across all groups.

2.6. Bias

To minimize selection bias, all eligible patients during the defined period were included consecutively. Diagnostic and classification criteria were standardized. However, as a retrospective study, it may still be subject to information bias due to potential variability in record completeness.

2.7. Study Size

The study population comprised all patients meeting inclusion criteria within the defined five-year period, resulting in a total sample size of 203 patients. No formal sample size calculation was conducted a priori, as the design was based on full inclusion of available cases.

2.8. Quantitative Variables (Item 11)

Age and Charlson Comorbidity Index (CCI) scores were treated as categorical variables, grouped based on clinically relevant cutoffs to facilitate comparison across strata. These groupings were selected to reflect developmental stages and

risk stratification commonly used in neurology.

2.9. Statistical Methods (Item 12)

Descriptive statistics summarized baseline characteristics. Kaplan-Meier survival analysis was used to estimate overall survival, and log-rank tests compared survival across groups. Cox proportional hazards regression was applied to assess the influence of covariates (age, hydrocephalus type, treatment modality, and CCI) on survival outcomes. Subgroup analyses were performed for hydrocephalus types and CCI categories. Patients with missing or incomplete survival data were censored in the analysis to maintain accuracy without imputation. Loss to follow-up was addressed by censoring cases at the last available date of contact. No formal sensitivity analyses were conducted; however, robustness of regression findings was supported through subgroup comparisons.

3. Results

A total of 203 patients diagnosed with hydrocephalus between 2019 and 2024 were included in this study. The majority of patients were aged ≥ 60 years (60.1%), and 53.2% were male. Non-communicating (obstructive) hydrocephalus was the most frequently observed classification (43.8%), followed by communicating hydrocephalus. Based on the Charlson Comorbidity Index (CCI), most patients had mild comorbidities (48.3%). Surgical management—including ventriculoperitoneal shunting (VPS) and extraventricular drainage (EVD)—was performed in 70.4% of cases, while the remaining 29.6% received non-operative management.

The most common etiology of non-communicating hydrocephalus was space-occupying lesions (SOL), particularly infratentorial tumors located in the cerebellum, cerebellopontine angle, medulla oblongata, and sellar/suprasellar regions. Supratentorial lesions in the parietal and temporal lobes were also prevalent, contributing to third and fourth ventricle compression. In contrast, communicating hydrocephalus was primarily attributed to spontaneous cerebrovascular events, such as subarachnoid hemorrhage (SAH) and intraventricular hemorrhage (IVH). Ex-vacuo hydrocephalus was commonly associated with a history of malignant ischemic stroke, whereas acquired hydrocephalus included 23 post-traumatic hydrocephalus (PTH) cases and 5 cases resulting from tuberculous meningitis.

Table 1. Baseline Characteristics of Included Hydrocephalus Patients (N = 203).

Variable	Category	n	%
Age Group (years)	<1	1	0.5%
	1–17	5	2.5%

Variable	Category	n	%
	18–40	17	8.4%
	41–59	42	20.7%
	≥60	122	60.1%
Gender	Male	108	53.2%
	Female	95	46.8%
Hydrocephalus Classification	Communicating	54	26.6%
	Non-communicating	89	43.8%
	Acquired	28	13.8%
	Congenital	4	2.0%
	Normotensive (NPH)	27	13.3%
Charlson Comorbidity Index	Ex-vacuo	1	0.5%
	None (CCI = 0)	33	16.3%
	Mild (CCI 1–2)	98	48.3%
	Moderate (CCI 3–4)	42	20.7%
	Severe (CCI > 4)	30	14.8%
Management Type	Operative	143	70.4%
	Conservative	60	29.6%

Notes:

- 1) Percentages are calculated based on the total number of subjects (N = 203).
- 2) Age groups and hydrocephalus types may overlap in specific diagnostic scenarios (e.g., congenital hydrocephalus typically <1 year, acquired can be post-traumatic or infectious).
- 3) "Normotensive" refers to Normal Pressure Hydrocephalus (NPH).

3.1. Survival Analysis

Kaplan–Meier survival analysis demonstrated variability in outcomes across age groups, although interpretation was limited in certain strata due to small sample sizes. The <1-year age group consisted of a single patient who survived throughout the observation period; the apparent 100% survival in this category should therefore be interpreted with caution given the negligible sample size and complete censoring. The lowest survival probability was observed in the 41–59 year age group (57.1%; hazard ratio [HR]: 13.8; 95% CI: 0.00–16.82; $p = 0.018$), followed by the 18–40 year group (64.7%) and those ≥60 years (72.5%). Although survival appeared poorest in middle-aged adults, wide confidence intervals around the HRs reflect limited statistical power, and these findings should be viewed as exploratory rather than definitive.

When stratified by treatment modality, patients who underwent surgical intervention had significantly better survival (73.3%) compared to those managed non-operatively (60.2%; HR: 1.649; 95% CI: 0.977–2.783; $p = 0.05$).

Survival analysis across hydrocephalus subtypes re-

vealed heterogeneity in outcomes. The ex vacuo category demonstrated the highest apparent survival rate (100%); however, this group contained only a single patient, and therefore the result is not statistically meaningful. Among subtypes with larger representation, survival was highest in normotensive hydrocephalus (80.0%), followed by communicating hydrocephalus (75.9%), congenital hydrocephalus (75.0%), and acquired hydrocephalus (66.7%). Patients with non-communicating (obstructive) hydrocephalus had the lowest survival rate (63.7%), with a hazard ratio of 14.4 (95% CI: 0.00–54.7; $p = 0.016$) compared with the reference group. These findings suggest a trend toward poorer outcomes in obstructive hydrocephalus, though interpretation must be tempered by the wide confidence intervals and unequal group sizes, indicating limited statistical power.

Gender-based analysis showed marginal differences in survival, with males having a survival rate of 70.2% and females 68.4% (HR: 1.069; 95% CI: 0.64–1.78; $p = 0.798$), indicating no statistically significant association between sex and outcomes.

3.2. Comorbidity-Stratified Survival

When adjusted for comorbidities, hydrocephalus outcomes varied notably. In patients without comorbidities, communicating hydrocephalus had the lowest survival (54.5%). In the mild CCI group, communicating hydrocephalus remained the lowest at 65.3%. For patients with moderate and severe comorbidities, acquired hydrocephalus exhibited the poorest outcomes, with survival rates of 62.5% and 33.3%, respectively.

4. Discussion

Hydrocephalus is a severe condition characterized by abnormal dilation of the cerebral ventricles, leading to decreased quality of life for affected individuals [4]. While untreated

hydrocephalus can result in progressive neurological injury and death, complete symptom resolution can be achieved with early diagnosis and surgical intervention [5]. Survival analysis revealed that age and hydrocephalus classification significantly influenced overall survival (OS). Patients under 1 year had the highest survival (100%), while those aged 41–59 years had the poorest outcomes (OS 57.1%, HR 13.8, $p = 0.018$). Among hydrocephalus types, ex-vacuo and normo-pressure had the best prognoses (OS 100% and 80%, respectively), whereas non-communicating hydrocephalus was associated with the lowest survival (63.7%) and highest risk of mortality (HR 14.4, $p = 0.016$). Gender showed no significant association with survival ($p = 0.798$). Operative management was associated with higher survival (73.3% vs. 60.2%), with a trend toward significance (HR 1.649, $p = 0.050$).

Table 2. Overall Survival and Hazard Ratio for Each Variable.

Age	OS	HR (95%CI)	p
<1	100%		
1-17	76.5%	4.74 (0.00-5.8)	0.014
≥18-40	64.7%	9.96 (0.00-12.1)	0.017
≥41-59	57.1%	13.8 (0.00-16.82)	0.018
≥60	72.5%	7.91 (0.00-9.645)	0.016
Classification			
Communicating	75.9%	8.97 (0.00-34.0)	0.014
Non-communicating	63.7%	14.4 (0.00-54.7)	0.016
Acquired	66.7%	11.9 (0.00-45.3)	0.015
Congenital	75%	0.85 (0.00 – 3.28)	0.014
Normo-pressure	80%	0.7 (0.00-2.72)	0.014
Ex-vacuo	100%		
Gender			
Male	70.2%		
Female	68.4%	1.069 (0.64 – 1.78)	0.798
Management			
Operative	73.3%		
Non-operative	60.2%	1.649 (0.977 – 2.783)	0.05

Hydrocephalus can occur at any age and is a leading cause of mortality and morbidity worldwide. However, there is heterogeneity in the reported prevalence and incidence of hydrocephalus, often without consideration of age or etiology.

A previous systematic review reported the highest prevalence of hydrocephalus in the elderly, reaching 175 per

100,000 individuals [6]. This finding aligns with the present study, which showed that 60% of subjects were over 60 years old. Prior studies have demonstrated a bimodal or ‘U-shaped’ incidence pattern in hydrocephalus, with an eight-fold decrease from pediatric to young adult populations followed by a seventeen-fold increase in the elderly. It is important to note

that hydrocephalus is a chronic disease, and the survival rates of pediatric hydrocephalus patients with operative care are relatively high. Consequently, it is possible that many adults with hydrocephalus may have stable disease since childhood and are less likely to seek medical management. This may be associated with “compensated/arrested hydrocephalus,” hypothesized as congenital hydrocephalus that remains inactive during the transition from childhood to adulthood but later decompensates and re-emerges in old age [7]. Additionally, cardiovascular risk factors in the elderly and white matter lesions influence outcomes in hydrocephalus patients, particularly in normal pressure hydrocephalus (NPH), followed by an increased risk of postoperative complications [8].

Non-communicating (obstructive) hydrocephalus was the most frequent subtype, followed by communicating forms. Within the non-communicating group, the most common causes were tumor-related obstructions, including infratentorial lesions such as fourth ventricular and cerebellar masses, as well as supratentorial tumors compressing the foramen of Monro or third ventricle. Other etiologies included aqueductal stenosis (congenital or acquired), congenital malformations such as Dandy–Walker malformation or foramen of Monro atresia, intraventricular hemorrhage with clot obstruction, posterior fossa or arachnoid cysts, and fourth ventricular outlet obstruction at the foramina of Magendie and Luschka. Less frequent causes were post-infectious adhesions (e.g., following tuberculous meningitis), post-operative or iatrogenic adhesions, and idiopathic cases where no definitive obstructing lesion could be identified.

This study found no association between sex and hydrocephalus outcomes across all types. However, males exhibited a higher incidence of hydrocephalus and higher survival rates than females. This difference in incidence has also been observed in previous studies, which reported hydrocephalus as more prominent in males [9]. In this study, no significant differences were found between sexes, consistent with earlier reports [10]. Some theories suggest a link between estrogen and increased neutrophil activation, which induces more severe ventricular dilation, white matter damage, and vasospasm, particularly in traumatic brain injury (TBI) following subarachnoid hemorrhage (SAH), thereby affecting survival rates [11].

In moderate and severe CCI groups, non-communicating or obstructive hydrocephalus exhibited the lowest survival rates. This may be attributed to the dominance of tumor etiology in the study subjects. Hydrocephalus is the most common disorder associated with certain types of tumors at specific locations, with symptoms and survival largely depending on the patient's age and the progression of hydrocephalus; however, other more tumor-specific symptoms may develop. Consequently, obstructive hydrocephalus caused by tumors is often the primary reason for symptom onset and can lead to significant morbidity and mortality. Patient survival with tumor-associated hydrocephalus is influenced by the severity of symptoms, the pathophysiological causes of hydrocephalus, and tumor-related factors (e.g., location, tumor diagnosis,

presence of metastasis), rather than hydrocephalus itself [12].

Adjusted for comorbidities, acquired hydrocephalus showed lower survival rates in both moderate and severe CCI groups. Surgical intervention showed a higher survival rate. In this study, acquired hydrocephalus was caused by central nervous system tuberculosis infection and post-traumatic hydrocephalus (PTH). A 2021 retrospective study on tuberculous meningitis (TBM) patients with hydrocephalus found that the presence of hydrocephalus on radiological imaging is associated with poorer prognosis and higher mortality rates. The study reported that hydrocephalus was seen in 44% of TBM patients and was an independent risk factor for poor outcomes, including death and severe disability. This aligns with previous findings indicating that radiological evidence of hydrocephalus significantly worsens prognosis in TBM patients, with an odds ratio (OR) of approximately 33 and a p-value near 0.049, indicating statistical significance [13]. Additionally, long-term neurological deficits such as cognitive impairment, hemiplegia, seizures, quadriplegia, and cranial nerve palsy are commonly observed in survivors of TB meningitis [14]. Communicating hydrocephalus occurs due to excessive CSF production or impaired CSF absorption in the subarachnoid space. Although less common, obstructive hydrocephalus can occur due to fourth ventricle outlet obstruction by inflammatory exudate [15]. The incidence of PTH in this study was 0.11%. A previous literature review reported PTH incidence ranging from 0.7% to 9% among all TBI patients [16]. In TBI, dynamic imbalance occurs between CSF production and absorption. Blood clot formation following intraventricular or subarachnoid hemorrhage causes CSF flow obstruction and acute hydrocephalus [17]. Subsequently, adhesions in the basal cisterns and inflammation result in impaired CSF absorption and chronic PTH [18]. Hydrocephalus has been associated with poor neurological outcomes in >65% of TBI patients in prior studies, as well as prolonged hospitalization and rehabilitation periods [19].

Acute hydrocephalus without treatment can lead to permanent brain damage, physical and mental impairment, and death. A previous systematic review showed higher survival rates in hydrocephalus patients who underwent shunting surgery, with improvement rates of 82%, low mortality rates of 0.2%, and lower complication rates of 8.2%. Shunting provides excellent outcomes in gait improvement and modest cognitive recovery, particularly in elderly individuals with NPH [20].

The limitations of this study include its inability to predict hydrocephalus outcomes beyond the study period. Hydrocephalus classification can be expanded based on etiology, including surgical and conservative management provided, to yield more specific survival outcomes. Nevertheless, this study is the first in Indonesia to report hydrocephalus patient survival rates across various etiologies.

5. Conclusion

This five-year retrospective study emphasizes the signifi-

cant impact of age, etiology, comorbidities, and treatment modality on survival in hydrocephalus patients. Surgical intervention, especially ventriculoperitoneal shunting, provides a survival advantage. The findings reinforce the importance of early diagnosis, stratified risk assessment using the Charlson Comorbidity Index (CCI), and individualized treatment strategies to improve patient outcomes. Future prospective studies with multicenter data are needed to validate these findings and optimize national guidelines for hydrocephalus care. This study represents a novel contribution as the first Indonesian investigation reporting survival outcomes in hydrocephalus patients across different etiologies using survival analysis and CCI stratification. The findings lay the groundwork for predictive modeling approaches in hydrocephalus management in the future.

Abbreviations

CCI	Charlson Comorbidity Index
CI	Confidence Interval
CSF	Cerebrospinal Fluid
EVD	External Ventricular Drainage
EI	Evans Index
HR	Hazard Ratio
KM	Kaplan–Meier
MRI	Magnetic Resonance Imaging
NPH	Normal Pressure Hydrocephalus
OS	Overall Survival
SAH	Subarachnoid Hemorrhage
SOL	Space-Occupying Lesion
TBM	Tuberculous Meningitis
TBI	Traumatic Brain Injury
VPS	Ventriculoperitoneal Shunt

Author Contributions

Kenzie Ongko Wijaya: Conceptualization, Data curation, Project administration, Writing – original draft

Nunki Puspita Utomo: Formal Analysis, Methodology, Resources, Software

Arya Taksya Bagaskara: Data curation, Investigation, Writing – original draft, Writing – review & editing

Endro Basuki Sadjiman: Conceptualization, Supervision, Validation, Visualization

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Conflicts of Interest

The authors declare no conflict of interest.

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