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Survival status and determinant factors of mortality among pediatric patients who underwent ventriculoperitoneal shunting surgery for hydrocephalus in Ethiopia

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Abstract

Background Ventriculoperitoneal (VP) shunting is one of the most common neurosurgical procedures for treating hydrocephalus. This study aimed to assess the Survival status and determinant factors of pediatric patients who underwent ventriculoperitoneal shunting for hydrocephalus.

Methods A multicenter institutional-based retrospective cohort study was employed by reviewing medical chart records of pediatric patients who underwent ventriculoperitoneal (VP) shunting surgery for hydrocephalus from 1/12/2015 to 30/02/2023 and the medical chart records review was employed from 1/03/2023 to 30/03/2023. Data were extracted using a pre-tested, structured questionnaire. The Cox proportional hazard model was used to identify determinants of pediatric patient survival, where the hazard ratio, p-values, and 95% CI for adjusted hazard ratio were used to test significance and interpret the results. A p-value of < 0.05 was considered statistically significant.

Results Seven hundred sixty-nine medical chart records of pediatric patients who underwent ventriculoperitoneal (VP) shunting surgery for hydrocephalus were selected and reviewed with a response rate of 87.89%. The median survival time of pediatric patients after surgery was 15 months. On the multivariable Cox proportional hazard model, ultrasound image (AHR: 4.257, 95% CI: 2.07–8.74), emergency type of surgery (AHR: 2.180, 95% CI: 1.20–3.95), additional procedures other than shunting (AHR: 2.089, 95% CI: 1.05–4.16), duration of stay (> 7 days) (AHR: 4.014, 95% CI: 1.28–12.57), shunt failure (AHR: 4.163, 95% CI: 2.32–7.47), and clinical follow-up (AHR: 2.606, 95% CI: 1.31–5.17) were found to be determinants factors of survival status the patients.

Conclusion The survival time to death was 15 months, and the mortality rate for shunting surgery for hydrocephalus was 24.58%. In this study, emergency type of surgery, additional procedures other than shunt, duration of stay (> 7 days), shunt failure, and no hospital follow-up were factors associated with the mortality of the patients.

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Keywords Hydrocephalus, Shunt, Ventriculoperitoneal, Pediatrics, Ethiopia

Introduction

Hydrocephalus is the most common neurosurgical condition in children. In it, cerebrospinal fluid (CSF) accumulates within the brain. [1]. It occurs due to birth defects and associated birth defects, including neural tube defects that result in aqueduct stenosis. Other causes include meningitis, brain tumors, traumatic brain injury, intraventricular and subarachnoid hemorrhage [2].

Shunt has been the main treatment modality for hydrocephalus and the most frequently utilized diversion procedure. It can be inserted into one of the brain's ventricles to the peritoneum cavity and acts as a drainage system for excess CSF from the brain into the abdomen where CSF is finally reabsorbed [3]. It is a simple surgical intervention performed by a neurosurgeon under general anesthesia in the sterile conditions of an operating theatre. [3, 4]. Shunting is the standard therapy for the management of hydrocephalus and it is one of the most commonly performed neurosurgical procedures, both on elective (87.3%) and emergency (12.7%) cases globally [5].

The latest advances in mechanical and optical equipment, as well as improved neuro endoscopes, have made endoscopic third ventriculostomy [ETV] a safer and preferable diagnostic procedure. At present, the procedure of choice for the treatment of obstructive hydrocephalus is ETV. Endoscopic Third Ventriculostomy became a preferred procedure due to lesser complications and no requirement of insertion and placing a foreign object for CSF diversion [6, 7].

The determinant factors affecting the survival status of children with hydrocephalus after VP.

shunt surgery includes premature infants, patients with a history of surgical excision of a mass lesion, congenital abnormalities, postcranial surgery hydrocephalus, or aqueduct stenosis, communicative hydrocephalus, post-traumatic brain injury, Emergency surgery, shunt obstruction, shunt infection, wound infection, disconnection, dislocation, migration breakage, and excessive drainage are common factors that affect the survival status of children [8–10].

In developed countries, the incidence of congenital hydrocephalus is 0.5–1/1000 live births, while that of acquired hydrocephalus is 3–5/1000 live births. There is no reliable incidence estimate for hydrocephalus in most developing countries; it is likely higher due to nutritional deficiencies, low infant birth weight, a greater incidence of perinatal and neonatal infections, and delayed antenatal diagnosis [11].

According to the world neurosurgery report, the survival of pediatric patients from shunt procedures is 79.14% [12]. A survey of pediatric acute care facilities reports that over 40,000 CSF shunts are placed annually in the USA [3] and more than 19,000 shunts in Africa [8]. Due to Limited resources, poor economic conditions, difficulty in following patients'causes, and in providing proper and timely care to these patients, shunt insertion is associated with higher complications in Sub-Saharan Africa [3, 13, 14].

The incidence of hydrocephalus is highest in Africa and Latin America (145 and 316 per 100,000 births, respectively) and lowest in the United States and Canada (68 per 100,000 births). It is higher in low- and middle-income countries (123 per 100,000 births than in high-income countries (79 per 100,000 births) [15]. There are 100,000 to 375,000 new cases of children with hydrocephalus each year in sub-Saharan Africa, with an annual economic burden as high as $1.4 to $56 billion [16]. Conservative estimates suggest a yearly incidence of 1.25 cases of pediatric hydrocephalus per 1000 births in East Africa and 3.500 new cases per 2.8 million births annually in Ethiopia [17].

In Ethiopia, the etiology and incidence rates of hydrocephalus can be assumed to correspond to what has been reported from other East African countries, where hydrocephalus has been estimated to have an infectious origin in the majority of cases because of a much higher prevalence of untreated neonatal or even prenatal infections. Based on a study conducted in Uganda by Warf, B.C., et al., post-infectious hydrocephalus is calculated to account for as much as 60% of the total pediatric hydrocephalus patient population [18, 19]. The findings of this research will help as an input and practical value for patients, health care providers, the Ministry of Health (MOH) (program planners related to pediatrics management with shunts for hydrocephalus), and researchers.

Method

Study area, study design, and study period

A multicenter institutional-based retrospective cohort study was employed by reviewing medical chart records of pediatric patients who underwent ventriculoperitoneal (VP) shunting surgery for hydrocephalus from 1/12/2015 to 30/02/2023 and the medical chart records review was employed from 1/03/2023 to 30/03/2023. This study was conducted in the capital city, Addis

Ababa, Ethiopia in public referral hospitals. According to the 2021 census, about 5,005,524 people live in the city [20].The city has 13 governmental hospitals, 9 non-governmental hospitals, and around 98 health centers. Out of the 22 hospitals, eight hospitals were provided VP shunt service.

Source population

All pediatric patients underwent ventriculoperitoneal shunting surgery in Addis Ababa from 1/12/2015 to 30/02/2023.

Study population

All selected children who underwent shunt surgery for hydrocephalus from 1/12/2015 to 30/02/2023 in Addis Ababa selected hospitals and who fulfilled the inclusion criteria.

Inclusion and exclusion criteria

All children whose charts were complete and available during data collection time were incorporated. Charts of children with incomplete forms and not available during data collection were excluded from the study.

Sample size determination and sampling procedure

The sample size was determined using power analysis for sample size calculation for survival analysis using the formula: $\boldsymbol{n} = \frac{\boldsymbol{d}}{\boldsymbol{P(event)}}.\boldsymbol{d} = \left(\boldsymbol{Z_{\alpha/2}} + \boldsymbol{Z_\beta}\right)^2 \frac{4}{\boldsymbol{In\Delta^2}}$
Where:

- ✓ n = total sample size
- ✓ d = No of observed events
- ✓ Δ = Hazard ratio $= -\ln(s(t)$
- ✓ $s(t) = 50\% = 0.5$: Because no previous study was found in the study area.
- ✓ P (event): Probability of the event occurring within the study period
- ✓ α: Level of significance (0.05)
- ✓ β: Power of the study (80%)
- ✓ $Z_{\alpha/2}$: 1.96
- ✓ Z_β : 0.84

$(\Delta = -\ln(s(t)) = -\ln(0.5) = 0.693)$.

Based on a two-sided 0.05 level test, the required number of events was:

$$d = \left(Z_{\alpha/2} + Z_\beta\right)^2 \frac{4}{In\Delta^2} = (1.96 + 0.84)^2 \frac{4}{In(0.693)^2} = 233$$

Hence, $n = \frac{d}{P(event)} = \frac{233}{0.5} = 466$

Adjusting for a loss of 20%, $n_{adj} = \frac{n}{1-loss} = \frac{466}{\text{<spanclass='convertEndash'>}1-0.2\text{}} \approx 583$.

Considering the design effect of 1.5 the final sample size was 583 × 1.5 = **875.**

First, hospitals found in Addis Ababa that deliver shunting services were selected. Among those hospitals providing VP shunt service, three hospitals were selected randomly using the lottery method. Then, ZMH, MCM, and TGH were selected by the lottery method. The number of surgeries done in ZMH, MCM, and TGH from 1/12/2015 to 30/02/2023, was 700, 294, and 250, respectively, as obtained from the HMIS and electronic records. The sample size was allocated proportionally to select the study participants from each hospital. Accordingly, medical cards of 492, 207, and 176 patients were selected by a simple random sampling technique.

Study variables

Dependent variable

Time to death or censoring (in months).

Independent variables

Socio-demographic and anthropometric factors:

- ✓ Age
- ✓ sex
- ✓ Weight
- ✓ Place of residency

Etiologic factors of hydrocephalus:

- ✓ Congenital (Aqueduct stenosis, Dandy-walker malformation, Spinal Bifida, Arachnoid cyst, Encephalocele)
- ✓ Acquired (Post-meningitis: Tumor, Post-traumatic brain injury, Hemorrhage)
- ✓ Idiopathic

Type of hydrocephalus:

- ✓ Obstructive hydrocephalus
- ✓ Communicative hydrocephalus
- ✓ Normal pressure hydrocephalus

Treatment factors:

- ✓ Pre -Operative treatment (prophylaxis antibiotics, investigations)
- ✓ Operative treatment (Side of shunt insertion, expertise of surgeon, type of shunting (initial or re-insertion), type of surgery (emergency or elective), surgical history)

✓ Post-Op treatments (duration of hospital stay, use of antibiotics)

Laboratory and imaging studies:

✓ Available imaging is done for diagnosis
✓ CSF sample taken (site, finding, type of pathogen)

Operational definitions

Event: The occurrence of death from initial shunt placement to the end of the study.

Censored; Pediatrics patients who underwent shunt surgery for hydrocephalus and did not develop the outcome of interest (death), were alive at the end of the follow-up period, or were lost to follow-up including discharged to home, discharged against medical advice or transferred out to other health institutions without knowing the outcome.

Survival time: The time from initial shunt placement to death or censoring in a month.

Data collection tools and procedures

Available information on the patient's medical records was observed, and an appropriate data extraction tool was prepared in English. The extraction tool is adapted from different related studies [8, 21, 22], which comprise socio-demographic and anthropometric factors of children, the etiology of hydrocephalus, types of hydrocephalus, treatment-related factors, and laboratory and imaging studies. Data collectors used the data extraction tool to collect the information from pediatric charts. Charts were retrieved using the children's registration number, which was found in the electronic recording system and HMIS log book in each selected hospital. The data collectors reviewed all medical records of patients who fulfilled the inclusion criteria in selected hospitals retrospectively from 1/12/2015 to 30/02/2023.

Data quality control

Three days of training were given to three data collectors with BSC degrees and one coordinator concerning the data collection tool and data collection process before the actual data collection period. A pretest was done before the actual data collection period at Saint Paul Hospital Millennium Medical 10% of the total sample size was checked with a structured extraction tool to check the usually recorded variables on the patient's medical record and modifications to the extraction tool were made. The principal investigator checked data completeness and consistency.

Data processing and analysis

After the completion of data collection, the collected data were checked thoroughly by observation for any inappropriate responses. Next, the data were entered into and cleared using Epi-Data version 7 and analyzed by STATA version 14.2 and SPSS version 26. To check the nature of data normality and the presence of outliers in data analysis we have used the following models. The Cox proportional hazard model was used to identify determinant factors affecting shunt survival. The fundamental assumption of the Cox proportional hazard model (hazard functions for two different levels of covariates are proportional for all values of t) was checked by goodness-of-fit (GOF), particularly the Schoenfeld residuals proportional hazard assumption test for the individual covariates, and global tests were used. Then, the data were described using relative frequency, percent, mean with standard deviation, and median based on its applicability. The Kaplan–Meier survival curve and the log-rank test were used to test for the presence of differences in survival among determinant variables. The hazard ratio obtained from the Cox proportional hazard model, with its 95% confidence interval and p-values, was used to measure the strength of the association and identify statistically significant results. A P-value <0.05 was considered statistically significant.

Ethical considerations

Ethical clearance and ethical approval were obtained from the Saint Peter Specialized Hospital Institutional Review Committee, whose ethical reference number was V111/01/03/2023. The Institutional Review Board (IRB) was waived for consent to participate in the research since the research could be done by medical record chart review without contacting the patients because the study was retrospective. A formal letter was submitted to each selected hospital's administrators to get permission for data collection. The Declaration of Helsinki was considered, and principles and recommendations were used.

Result

Socio-demographic and anthropometric factors

Among the total sample size (875), 769 (87.89%) charts met the criteria for final analysis; 106 charts were excluded (50 incomplete data and 56 of the charts were not available at the time of data collection). Of these, about 448 (58.26%) of the study participants were males, and the majority of them, 465 (60.47%), came from rural areas (Table 1). The median age at the time of admission was 7 months, with the youngest being 0.06 (2 days) and the oldest being 167, and the median weight at the time

Table 1 Socio-demographic and anthropometric factors of pediatric patients managed with a shunt for hydrocephalus at selected hospitals, Addis Ababa, Ethiopia, 2023 ($n = 769$)

		Outcome		
Covariate	**Category**	**Censored N (%)**	**Death N (%)**	**Total N (%)**
Age(month)	< 6	235 (69.94%)	101 (30.06%)	336 (43.69%)
	6–12	144 (80.90%)	34 (19.10%)	178 (23.15%)
	12–59	121 (73.78%)	43 (26.22%)	164 (21.33%)
	59–168	80 (87.91%)	11 (12.09%)	91 (11.83%)
Sex	Male	350 (78.12%)	98 (21.88%)	448 (58.26%)
	Female	230 (71.65%)	91 (28.35%)	321(41.74%)
Weight (Kg)	< 6	119 (77.27%)	35 (22.73%)	154 (20.03%)
	6–12	296 (75.90%)	94 (24.10%)	390 (50.72%)
	> 12	165 (73.33%)	60 (26.67%)	225 (29.26%)
Residence	Rural	350 (% 75.27)	115 (24.73%)	465 (60.47%)
	Urban	230 (75.66%)	74 (24.34%)	304 (39.53%)

of admission was 9.9 kg, with the smallest being 2 and the largest being 48.99.

Etiology and type of hydrocephalus factors

Out of the total participants congenital etiology accounts for 469 (61%), acquired 268 (34.9%) and 32 (4.1%) cases develop from unknown cause. The majority of participants had the obstructive type of hydrocephalus, 446 (58%) followed by communicative hydrocephalus, 286 (37.19%), and NPH 37 (4.81%) (Table 2).

Laboratory and imaging studies factors

Pediatric patients whose hydrocephalus was diagnosed with the help of only a CT scan accounts for 380 (49.41%), only U/S 147 (19.12%), only MRI 340 (44.21%), both MRI and CT constitute 138 (17.95%) and 43 (5.59%) have no documented imaging. From the total analyzed participants, CSF culture was done for 582 (75.68%) patients, and 290 (49.74%) were culture positive; from this 110 (37.93%) were gram-negative (Table 3).

Clinical management-related factors

Preoperative and operative management-related factors

Most of the participants (91.68%) had documented preoperative investigations; out of these, CBC 502 (65.28%), serology 383 (49.80%), and 64 (8.32%) had no documented investigation. The prophylaxis was given to 562 (73.88%) patients. Out of the total operation, emergency surgery accounted for 129 (16.78%), elective surgery was 640 (83.22%), and 108 (14.04%) patients were operated on by pediatric neurosurgeons. The median duration of hospital stay was 5 days, with a minimum of 1 and a maximum of 70 days, and the median duration since the initial shunt was 24 months (Table 4).

Moreover, 228(29.65%) had signs of shunt failure. From these, obstruction accounts for 54(23.28%), shunt

Table 2 Etiology and type of hydrocephalus factors of pediatric patients managed with a shunt for hydrocephalus at selected hospitals, Addis Ababa, Ethiopia, 2023 ($n = 769$)

		Outcome		
Variable	**Category**	**Censored N (%)**	**Death N (%)**	**Total N (%)**
Congenital: $n = 469$	Unclassified	48 (97.96%)	1 (2.04%)	49 (10.44%)
	Aqueduct stenosis	37 (60.66%)	24 (39.34%)	61 (13%)
	Dandy-walker malformation	51 (68.92%)	23 (31.08%)	74 (15.77%)
	Chiari malformation	29 (70.73%)	12 (29.27%)	41 (8.74%)
	Spinal bafida	137(80.58%)	33 (19.42%)	170 (36.24%)
	Arachnoid cyst	25 (100%)	0 (0.00%)	25 (5.33%)
	Encephalocele	41 (83.67%)	8 (16.33%)	49 (10.44%)
Acquired: $n = 268$	Post-meningitis	43 (68.25%)	20 (31.75%)	63 (23.51%)
	Tumor	28 (66.67%)	14 (33.33%)	42 (15.67%)
	Post-traumatic brain injury	26 (56.52%)	20 (43.48%)	46 (17.16%)
	Hemorrhage	39 (79.59%)	10 (20.41%)	49 (18.28%)
	Post-surgical	32 (78.04%)	9 (21.96%)	41 (15.29%)
	Pseudo tumor cerebral	22 (81.48%)	5 (18.52%)	27 (10.07%)
Idiopathic: $n = 32$		23 (71.86%)	9 (28.12%)	32 (100%)
Types of hydrocephalus:	Communicative	212(74.13%)	74 (25.87%)	286 (37.19%)
	Obstructive	333(74.66%)	113 (25.34%)	446 (58.00)
	Normal pressure	35 (94.59%)	2 (5.41%)	37 (4.81%)

Table 3 Laboratory and imaging studies factors of pediatric patients managed with a shunt for hydrocephalus at selected hospitals, Addis Ababa, Ethiopia, 2023 ($n = 769$)

		Outcome		
Variable	**Category**	**Censored N (%)**	**Death N (%)**	**Total N (%)**
Imaging was done for diagnosis	CT	312 (82.11%)	68 (17.89%)	380 (49.41%)
	Ultrasound	70 (47.62%)	77 (52.38%)	147 (19.12%)
	MRI	282 (82.94%)	58 (17.06%)	340 (44.21%)
	CT & MRI	125 (16.25%)	13 (1.70%)	138 (17.95%)
	Not documented	37 (86.05%)	6 (13.95%)	43 (5.59%)
CSF sample was taken?	Yes	478 (82.13%)	104 (17.87%)	582 (75.68%)
	No	102 (54.55%)	85 (45.45%)	187 (24.32%)
Finding:	No growth	263 (89.76%)	30 (10.24%)	293 (50.26%)
	Positive culture	216 (74.48%)	74 (25.52%)	290 (49.74%)
Type of pathogen:	Gram-negative rods	72 (65.45%)	38 (34.55%)	110 (37.93%)
	No gram reaction	87 (95.60%)	4 (4.40%)	91 (31.38%)
	Gram positive cocci	57 (64.04%)	32 (35.96%)	89 (30.69%)

Table 4 Operative management-related factors of pediatric patients managed with a shunt for hydrocephalus at selected hospitals, Addis Ababa, Ethiopia, 2023($n = 769$)

		Outcome		
Variable	**Category**	**Censored N (%)**	**Death N (%)**	**Total N (%)**
Type of surgery:	Emergency	46 (35.67%)	83 (64.34%)	129 (16.78%)
	Elective	534 (83.44%)	106 (16.56%)	640 (83.22%)
Type of shunt procedure:	Initial	464 (75.94%)	147 (24.05%)	611 (79.45%)
	Revision	116 (73.42%)	42 (26.58%)	158 (20.55%)
Side of shunt:	Right-sided	554 (76.00%)	175 (24.00%)	729 (94.80%)
	Left-sided	26 (65.00 %0	14 (35.00%)	40 (5.20%)
Procedure other than shunt:	Craniotomy	36 (57.14%)	27 (42.86%)	63 (8.19%)
	MMC repair	172 (76.44%)	53 (23.56%)	225 (29.26%)
	Cranioplasty	34 (64.15%)	19 (35.85%)	53 (6.89%)
	Endoscopic fenestration	26 (57.78%)	19 (42.22%)	45 (5.85%)
	EVD	28 (48.28%)	30 (51.72%)	58 (7.54%)
	No procedure	284 (87.38%)	41 (12.62%)	325 (42.26%)
Expertise of surgeon:	Consultant	501 (75.91)	159 (24.09%)	660 (85.83%)
	3rd years resident	7 (50.00%)	7 (50.00%)	14 (1.82%)
	4 th years resident	8 (44.44%)	10 (55.56%)	18 (2.34%)
	5 th years resident	64 (83.12%)	13 (16.88%)	77 (10.01%)
Specialty of neurosurgeon:	Pediatrics neurosurgeon	99 (91.67%)	9 (8.33%)	108 (14.04%)
	Non-pediatrics neurosurgeon	481 (72.77%)	180 (27.23%)	661 (85.96%)
Site of proximal catheter:	Right	546 (75.10%)	181 (24.90%)	727 (94.54%)
	Left	20 (80.00%)	5 (20.00%)	25 (3.25%)
	Frontal	10 (83.33%)	2 (16.67%)	12 (1.56%)
	Occipital	4 (80.00%)	1 (20.00%)	5 (0.65%)
Site of distal catheter:	Peritoneum	520 (75.58%)	168 (24.42%)	688 (89.47%)
	Atrium	8 (57.14%)	6 (42.86%)	14 (1.82%)
	Thorax	17 (70.83%)	7 (29.17%)	24 (3.12%)
	External	35 (81.40%)	8 (18.60%)	43 (5.59%)

infection 53(23.25%), over drainage 36(15.79%), and others (disconnection, migration, breakage, and extrusion) 86 (37.68%) (Table 4).

About half of the participants, 389 (50.59%) had follow-up after shunt insertion, and subjective complaints during follow-up such as rapid increase in head size accounts 26 (6.68%), developmental delay 31 (7.97%), seizure 80 (20.57%), irritability/drowsiness 82 (21.08%), nausea/vomiting 96 (24.68%), headache 115 (29.56%), urinary/fecal incontinence 77 (19.79%), vision disturbance 13 (3.34%), and gait disturbance 91 (23.45%). At the same time, the signs those patients manifested on follow-up were a visual deficit of 30 (7.71%), a sunset eye appearance of 62 (15.98%), a rapid increase in head size of 81 (25.2%), distention of the scalp vein of 105 (26.99%), loss of consciousness of 21 (5.4%), fever of 108 (27.76%), and abdominal tenderness of 36 (9.25%) (Table 5).

Survival function and Comparison of Survivorship Functions for different variables

The test statistics, which are obtained from the log-rank test, showed that there was a significant difference in survival function (curve) for different categorical variables, as shown in. Table 6.

The median survival time for those who had a history of post-traumatic brain injury was (13.000 months, 95% CI: 8.68–17.32) lower than the median survival time of individuals who did not have post-traumatic brain injury (19.000 months 95% CI: 15.18–22.83). This difference was statistically significant with a log-rank p-value <0.005 (Fig. 1).

The median survival time of pediatric patients who stayed greater than a week or more than a week (≥ 7 days) was (25.688 months, 95% CI: 2.09–27.09) lower than the median survival time of individuals stay a week (< 7 days) was (48.000 months 95% CI: 15.09–18.40). This difference was statistically significant with log-rank p value <0.000 (Fig. 2).

Determinants of mortality

The relationship between the baseline variables and the risk of mortality was analyzed using the Cox proportional hazard regression model. From the univariate analysis of independent variables at a 25% level of significance, age, etiology, ultrasound, MRI, type of pathogen, no investigation, type of surgery, procedure other than shunt, a specialty of neurosurgeon, duration of hospital stay, duration of antibiotic therapy, metronidazole, vancomycin, mannitol, clinical follow-up, and shunt failure were significantly associated with determinants of pediatric patients' survival time.

Table 5 Medical management-related factors of pediatric patients managed with a shunt for hydrocephalus at selected hospitals, Addis Ababa, Ethiopia, 2023($n=769$)

		Outcome		
Variable	**Category**	**Censored N (%)**	**Death N (%)**	**Total N (%)**
Duration of antibiotic therapy:	less than a week	435 (80.41%)	106 (19.59%)	541 (70.35%)
	One week or more	145 (63.60%)	83 (36.40%)	228 (29.65%))
Antibiotics given:	Ceftriaxone Yes	460 (75.78%)	147 (24.22%)	607 (78.93%)
	No	120 (74.07%)	42 (25.93%)	162 (21.07%)
	Amoxicillin Yes	44 (97.78%)	1 (2.22%)	45 (5.85%)
	No	536 (74.17%)	187 (25.83%)	724 (94.15%)
	Augmentin Yes	43 (81.13%)	10 (18.87%)	53 (6.89%)
	No	537 (75.00%	179 (25.00%)	716 (93.11%)
	Metronidazole Yes	193 (70.18%)	82 (29.82%)	275 (35.76%)
	No	387 (78.34%)	107 (21.66%)	494 (64.24%)
	Vancomycin Yes	75 (67.57%)	36 (32.43%)	111 (14.43%)
	No	505 (76.75%)	153 (23.25%)	658 (85.57%)
	SteroidYes	121(69.94%)	52 (30.06%)	173 (22.53%)
	No	459 (30.06%)	137 (69.94%)	596 (77.47%)
	Mannitol Yes	117 (66.10%)	60 (33.90%)	177 (23.02%)
	No	463 (75.65%)	129 (24.35%)	592 (76.98%)
	Anticonvulsant Yes	124 (68.51%)	57 (31.49%)	181 (23.57%)
	No	456 (77.55%)	132 (22.45%)	588 (76.43%)
	Others Yes	93 (98.94%)	1 (1.06%)	94 (12.22%)
	No	487 (72.15%)	188 (27.85%)	675 (87.78%)

Others* (Gentamycin, Cloxacillin, Ampicillin, Azithromycin)

Table 6 Median survival time and log-rank test for equality of survivor functions among pediatric patients who managed with a shunt for hydrocephalus at selected hospitals, Addis Ababa, Ethiopia, 2023($n = 875$)

Variables		Survival time in month	
		Median (95%CI)	**Log rank test (*p*-value)**
Post-traumatic brain injury	Yes	13.00(8.678–17.322)	0.004
	No	19.000 (15.175–22.825)	
Ultrasound	Yes	15.00 (13.208–26.792)	0.000
	No	23.00 (15.164–19.836)	
Type of surgery	Emergency	6.000 (0.000–13.644)	0.002
	Elective	19.863 (2.121–15.707)	
Hospital stay	< 7 days	48.000 (15.097–18.409)	0.000
	≥ 7 days	25.688 (2.095–27.097)	
Duration of antibiotic therapy	Less than a week	19.863 (2.121–15.707)	0.0701
	One week or more	11.000(7.870–14.130)	
Shunt failure	Yes	12.000 (5.057–18.943)	0.000
	No	19.341 (19.343–25.935)	

However, only age, ultrasound, pathogen, type of surgery, procedure other than shunt, duration of hospital stays, clinical follow-up, and shunt failure were found to be significantly associated with determinants of pediatric patients'survival time in a multivariable Cox proportional hazard model at 5% level of significance.

The result of the multivariable analysis revealed that, after adjusting for other variables, patients in the age range of 59–168 months had a 67.5% lower rate to determine survival time compared with patients <6 months (AHR: 0.325, 95%CI: 0.109, 0.967). Those pediatric patients who were diagnosed by ultrasound were 4.257 times more likely to die as compared to those who had CT and MRI diagnosed (AHR: 4.257, 95%CI: 2.073, 8.744) (Table 7).

The gram-positive type of pathogen had an 80.1% lower rate of determining survival time than the gram-negative type of pathogen (AHR: 0.199, 95% CI: 0.063, 0.631). On the other hand, the emergency type of surgery had 2.180 times more chance of determining pediatric patients'survival time as compared to the elective type of surgery (AHR: 2.180, 95% CI: 1.202, 3.955) and those patients who had additional procedures other than shunt procedure were 2.089 times more likely to die than those who had only shunt procedure (AHR: 2.089, 95% CI: 1.050, 4.156). Moreover, patients whose duration of hospital stay was a week or more had 4.014 times more chance of death than those who stayed less than a week (AHR: 4.014, 95%CI: (1.282, 12.57) (Table 7).

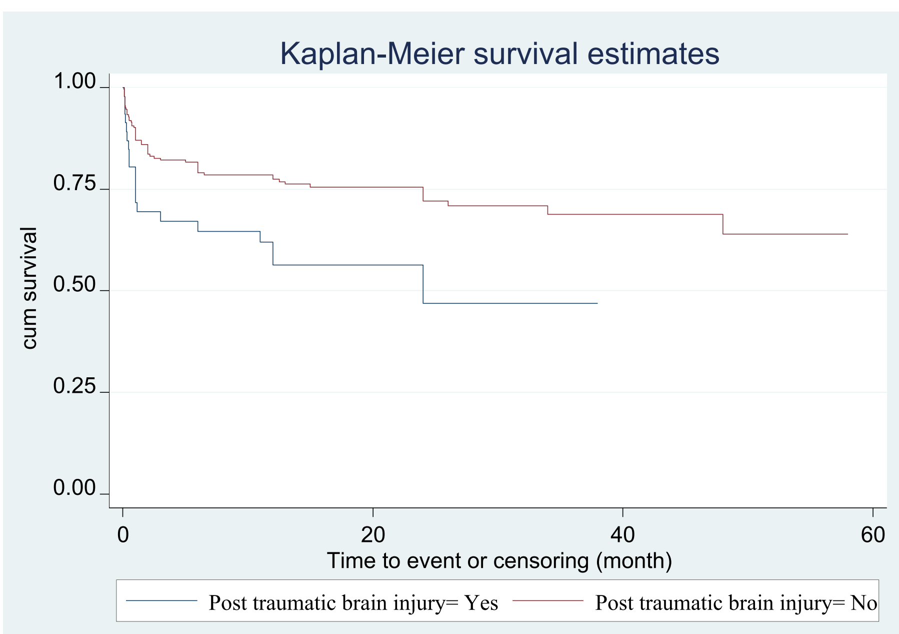

Fig. 1 Kaplan–Meier survival estimation of time to event or censoring in pediatric patients who managed with shunt surgery for hydrocephalus regarding post-traumatic brain injury at selected hospitals, Addis Ababa, Ethiopia, 2023

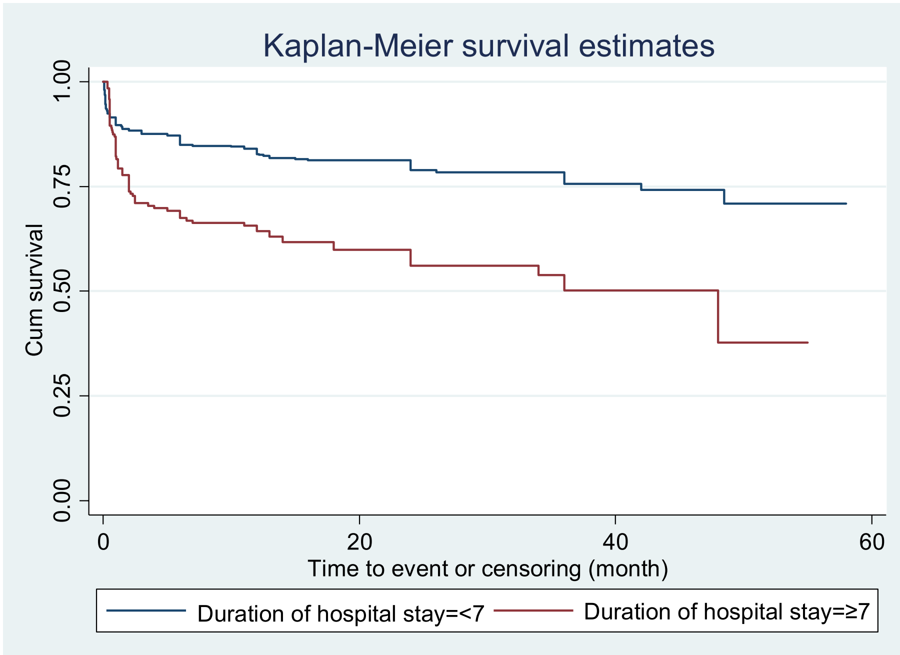

Fig. 2 Kaplan–Meier survival estimation of time to event or censoring of hospital stay duration among pediatric patients who managed with shunt surgery for hydrocephalus at selected hospitals, Addis Ababa, Ethiopia, 2023

Pediatric patients who had shunt failure were 4.163 more likely prone to death than those who did not have shunt failure (AHR: 4.163, 95%CI: 2.320, 7.472) and those patients who did not have hospital follow-up were 2.606 more likely to have an event compared to patients who had clinical follow up (AHR: 2.606, 95% CI: 1.312, 5.175) (Table 7).

Discussion

This retrospective medical chart review study aimed to assess determinants of the survival status of pediatric patients who managed shunt surgery for hydrocephalus. During the review period, about 189 (24.58%) patients died. The number of deaths is not similar to other studies. The discrepancy in results that have been seen among studies might be different in sample size, study design, and study period. This finding estimates mortality by 7 years retrospectively. The other possible explanation might be the difference in the study area, and there might be an acceptable quality of patient care due to economic capability. The total number of deaths that occurred in this study was lower than the studies conducted in Uganda (32.4%) [8] and Pakistan (28.9%) [22]. But the number of deaths was higher than reports from India 23.5% and World Neurosurgery Association 20.8% [23, 24]. In this study, the overall median survival for patients who had shunt surgery was 15 months. Due to a large number of censored observations (75.42%) in our study, this finding was lower than the studies in which the median survival was 18.1 months in Pakistan [22], 19 months in India [3], 17 months in Korea [25], 15.7 months in Kenya [9] and 15.6 months in Nigeria [5].

This study showed that age has a statistically significant effect on the survival of pediatric patients. Patients in the age range of 59–168 months had a 67.5% lower determined survival time as compared to those with pediatric patients whose age was <6 months. The reason might be an increase in awareness of danger signs and reporting as age increases, as well as the high prevalence of congenital causes and the lack of early shunt management because of poor healthcare setup and human resources. Waiting for shunt surgery can decrease the survival of patients. This is not in line with a study conducted in Pakistan [26].

This study also revealed that an ultrasound diagnostic imaging study shows significance in determining the survival of pediatric patients managed with a shunt for hydrocephalus. Patients diagnosed with ultrasound imaging were 4.257 times more likely to survive than those who were diagnosed with CT and MRI. The difference may be due to the high detection power of CT and MRI, which are recommended for brain imaging rather than ultrasound. This result is in line with a study conducted in Canada [27, 28].

Our study shows that a gram-negative type of pathogen was found to be a statistically significant determinant of survival time in pediatric patients managed with

Table 7 Results of the bivariable and multivariable Cox regression analysis of pediatric patients who were managed with a shunt for hydrocephalus at selected hospitals, Addis Ababa, Ethiopia 2023 ($n = 875$)

Predictors	CHR (95% CI)	*P* value	AHR (95% CI)	*P* value
Age (months)				
< 6	1		1	
6–12	0.604 (0.410,0.892)	0.011	0.623 (0. 299, 1.290)	0.202
12–59	0.869 (0.608, 1.243)	0.443	1.040 (0. 539, 2.005)	0.906
59–168	0.369 (0.198, 0.689)	0.002	**0.325 (0.109, 0.967)**	**0.043***
Etiology of hydrocephalus				
Congenital	1		1	
Acquired	1.359 (1.010, 1.828)	0.043	1.481 (0.823, 2.664)	0.190
Ultrasound Yes	3.805 (2.840, 5.097)	0.000	**4.257 (2.073, 8.744)**	**0.000***
No	1		1	
Type of pathogen				
Gram-negative	1		1	
No gram reaction	1.104 (0.688, 1.771)	0.680	1.276 (0.722, 2.256)	0.401
Gram-positive	0.107 (0.038, 0.301)	0.000	**0. 199 (0.063, 0.631)**	**0.006***
Preoperative investigations				
No investigation	3.775 (2.640, 5.396)	0.000	1.460 (0.751, 2.840)	0.264
Type of surgery				
Emergency	0.198 (0.148, 0.265)	0.000	**2.180 (1.202, 3.955)**	**0.010***
Elective	1		1	
Procedures other than shunt				
Yes	0.305 (0.215, 0.432)	0.000	**2.089 (1.050, 4.156)**	**0.036***
No	1		1	
Specialty of neurosurgeon				
Pediatric Neurosurgeon	1		1	
Nonpediatric neurosurgeon	3.597 (1.841, 7.027)	0.000	1.717 (0.640, 4.604)	0.282
Duration of hospital stay				
< 7	1		1	
> 7	2.306 (1.723, 3.086)	0.000	**4.015 (1.282, 12.57)**	**0.017***
Duration of antibiotic therapy				
Less than a week	1		1	
One week or more	2.261 (1.689, 3.029)	0.000	1.957 (0.667, 5.740)	0.221
Antibiotics type given				
Metronidazole Yes	1.551 (1.162, 2.072)	0.003	1.288 (0.698, 2.377)	0.417
No	1		1	
Vancomycin Yes	1		1	
No	0.652 (0.453, 0.939)	0.022	2.136 (0.906, 5.037)	0.083
Mannitol Yes	1		1	
No	0.596 (0.438, 0.811)	0.001	1.306 (0. 680, 2.509)	0.422
Hospital follow-up Yes	1		1	
No	6.047 (4.072, 8.980)	0.000	**2.606 (1.312, 5.175)**	**0.006** *
shunt failure Yes	6.822 (4.981, 9.343)	0.000	**4.163 (2.320, 7.472)**	**0.000***
No	1		1	

CHR Crude hazard ratio, *AHR* Adjusted Hazard Ratio, *CI* Confidence interval

* Statistically significant

a shunt for hydrocephalus. The gram-positive type of pathogen was 80.1% lower to determine the survival time of patients than the gram-negative type of pathogen. The reason is that gram-negative types of pathogens are associated with high mortality because they are resistant to multiple drugs and are increasingly resistant to most available antibiotics. These bacteria have built-in abilities to find new ways to be resistant and can pass along genetic materials that allow other bacteria to become drug-resistant as well. A high prevalence of gram-negative bacteria may also be a possible reason relative to gram-positive bacteria. This is also consistent with the study in Kenya and Hong Kong [29, 30].

In this study, the type of surgery was a significant determinant of pediatric patients'survival managed with a shunt for hydrocephalus. Accordingly, the emergency type of surgery was 2.180 times more likely to determine the survival time of pediatric patients than the elective type of surgery. The variation among types of surgeries might be due to poor outcomes in emergency cases (in many cases, it is a do-or-die situation) rather than elective cases. Elective patients have undergone a full preoperative evaluation, which is important to manage further complications during and after surgery. High coordination of operative teams so as not to give time to the occurrence of further complications is mainly in elective surgery, and the quality of the surgeon may also contribute to the survival of patients (elective surgery is mainly done by consultants). This significance is not in line with a study in Cuba and India [9, 31].

A procedure other than a shunt was another significant determinant of pediatric patients'survival managed with a shunt for hydrocephalus. Patients who had additional procedures other than shunt surgery had 2.089 times shorter survival times than patients who had only shunt surgery. This might be due to poor survival status in the case of any neurosurgery and worse in other procedures in addition to shunting. This is similar to the study conducted in Korea [29].

The duration of hospital stay was also a statistically significant determinant of pediatric patients'survival managed with a shunt for hydrocephalus in the current study. Patients who stay greater than or equal to seven days ($\geq$ 7 days) were 4.014 times more likely to die than those patients who stay < 7 days. This might be due to the complicated nature of cases after surgery. If a patient had no complications, a shorter hospital stay and a shorter antibiotic treatment time would be indicated. Patients who develop complications need to stay longer for better treatment or management. Generally, the longer the stay and treatment time, the more complications the patient might have; the more complications the patient has, the more chance the patient has to die. This finding is inconsistent with reports from Pakistan [5, 22].

According to this study, patients who had shunt failure were 4.163 times more likely to die than those who didn't have shunt failure. The possible explanation might be due to the high chance of death in cases of those fatal types of shunt failure (shunt blockage, shunt infection, and shunt dislocation) and the proneness of revision shunts, which increase infection and destruction of ventricular and neural pathways. If patients need shunt re-insertion, they stay with the disease until the second procedure. Therefore, the long-lasting disease could end up with a shorter survival time compared to those who had not had shunt failure. This is true for studies in India [3] and Korea [25].

This study revealed that regular clinical follow-up significantly determines pediatric patient survival managed with a shunt for hydrocephalus. Those patients who did not have regular hospital follow-up were 2.606 times more likely to die than those with regular clinical follow-up. The reason might be detecting and treating complications early during follow-up visits. This is similar to studies in India [3].

Conclusion and recommendation

The average time to death was 15 months, and the mortality rate for shunting surgery for hydrocephalus was 24.58%. In this study, emergency type of surgery, additional procedures other than shunt, duration of stay (> 7 days), shunt failure, and clinical follow-up were factors associated with the mortality of the patients. The healthcare provider should give special emphasis to patients who underwent shunt surgery and know factors particularly those identified as determinants of death in this study. Better to use recommended brain imaging studies (CT and MRI) than Ultrasound. During discharge, the patients should be, informed about regular follow-up times and to visit at any time in case of danger signs and symptoms. A prospective study is strongly encouraged to follow the long-term outcome of patients who managed with a shunt for hydrocephalus.

Strengths and limitations of the study

It is a representative study as it is a multicenter study from both public and private institutions and the data included five years of data. Since the data was collected from a secondary source; some important determinants were missed which might have been significant determinants of mortality. Large censored observations (75.42%), might have missed important data and events within the observation period.

Abbreviations

AAHB	Addis Ababa Health Bureau
AHR	Adjusted hazard ratio
CI	Confidence interval CHR- crude hazard ratio
CSF	Cerebrospinal fluid
CT	Computed tomography scan
EVD	External ventricular drainage
ETV	Endoscopic third ventricles
HMIS	Health Management Information System

HR	Hazard ratio
ICP	Intracranial pressure
MOH	Ministry of health
MMC	Myelomeningocele
MRI	Magnetic resonance imaging
OR	Operation room
U/S	Ultrasound
USA	United States of America
VPS	Ventriculoperitoneal shunt
WHO	World health organization

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Data availability
The data of this study will be available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Ethical clearance and ethical approval were obtained from the Saint Peter Specialized Hospital Institutional Review Committee, whose ethical reference number was V111/01/03/2023. The Institutional Review Board (IRB) was waived for consent to participate in the research since the research could be done by medical record chart review without contacting the patients because the study was retrospective. A formal letter was submitted to each selected hospital's administrators to get permission for data collection. The Declaration of Helsinki was considered, and principles and recommendations were used.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

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