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Original Investigation

Ventriculoperitoneal (VP) Shunt Survival in Patients Developing Hydrocephalus After Cranial Surgery

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ABSTRACT

AIM: Ventriculoperitoneal (VP) shunt insertion remains the most popular method for the treatment of hydrocephalus despite its associated complications. We assessed VP shunt survival in a group of patients who had developed hydrocephalus following cranial surgery.

MATERIAL and METHODS: A retrospective charts review was done over a 10-year period at our institution. Kaplan-Meier survival curves and Log-Rank (Cox-Mantel) test were used to analyze various factors affecting VP shunt survival.

RESULTS: Among the 67 cases included, a total of 28 (46.3%) patients had undergone cranial surgery for brain tumors. The overall rate of shunt failure was 14.9% at a mean follow-up of 16 months. Shunt failure in pediatric patients (20%) was slightly higher than that in adult patients (13.5%). The median time to first shunt failure was adversely influenced by a history of brain tumor ($p = 0.019$), prolonged antibiotic therapy ($p = 0.018$) and administration of steroids ($p = 0.004$).

CONCLUSION: Shunt survival was worse in patients who developed hydrocephalus following cranial surgery performed for brain tumors and those who received either steroids or prolonged antibiotic therapy. Thus post-cranial surgery hydrocephalus represents a unique subset of hydrocephalus.

KEYWORDS: Ventriculoperitoneal shunt, Hydrocephalus, Post-cranial surgery hydrocephalus, Shunt survival, Shunt complication, Shunt failure

INTRODUCTION

Hydrocephalus results from abnormal production, flow or absorption of cerebrospinal fluid (CSF) causing an "active distension" of ventricles of the brain (40). Left untreated, this condition can lead to rapid deterioration and adverse long-term outcomes, both in pediatric (45) and adult (28) patients. Prompt CSF diversion with ventriculoperitoneal (VP) shunt insertion remains the most popular treatment for hydrocephalus (17).

A number of classification schemes have been proposed to categorize hydrocephalus (3, 22, 32, 33, 37). However, no single scheme is comprehensive enough to encompass all aspects of this diverse entity (40). The development of hydrocephalus following cranial surgery is a well-recognized phenomenon (29) and results from a combination of collateral damage incurred during the surgical procedure (19) and the alterations occurring later in the CSF circulation, cerebral blood flow (CBF) auto-regulation and cerebral compliance (47).

Complications resulting from VP shunts are notoriously common (7, 9, 13, 24) and have been a subject of extensive research. (26, 27, 51) However, only a few studies have focused on VP shunt survival in patients who develop hydrocephalus as a consequence of cranial surgery itself. In this study, we report our experience of managing post-cranial surgery hydrocephalus in both pediatric and adult patients with particular emphasis on shunt complications and factors influencing shunt survival.

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MATERIAL and METHODS

A retrospective charts review was performed using the in-patient database at our institution. Confidentiality of patients' records was maintained and access to file records was strictly restricted to only concerned personnel. The study was exempted from formal ethical approval as per the institutional policy. Files were retrieved using ICD-9-CM (International Classification of Diseases, 9th Revision-Clinical Modification) codes for "hydrocephalus" as the discharge diagnosis, and "ventriculoperitoneal shunt" as part of the procedure performed, so as to include all insertions and revisions. For the purpose of analysis, adult patients were defined as those who were 18 years of age or older. Each file was individually reviewed for patient demographics, clinical features, laboratory and radiological work-up, medical and surgical management, hospital stay and subsequent course. Clinical notes from consultations in neurosurgery clinics were specifically reviewed for the development of new complaints, any persistent symptoms and neurological deficits in terms of vision, cognition or motor function. Findings from shunt assessment were also recorded and, in cases of shunt malfunction, the cause and delay from first insertion to shunt revision was noted. Furthermore, for pediatric patients, data regarding antenatal ultrasound reports, mode of delivery and gestational age at birth were also collected.

All patients who developed hydrocephalus after cranial surgery (which was not noted on pre-operative scans) were included in the study. The primary outcome of interest was shunt failure and revision rate. For the purpose of this study, the definition of shunt failure proposed by Reddy et al (39) was used. Furthermore, shunt failure was categorized as: shunt infection, blockade and migration, cerebrospinal fluid ascites, or failure caused by an unknown factor.

Data was recorded using a structured, pre-tested questionnaire. For descriptive data, frequency, mean and standard deviation were calculated. Pearson's chi-square test, Student's t-test and Mann-Whitney U test were used for comparison of proportions, means and medians respectively. A p-value of <0.05 was considered statistically significant in all cases. Kaplan-Meier curves were used to determine the duration from shunt placement to first malfunction. The Log Rank (Mantel-Cox) test was used to determine factors affecting shunt survival. Statistical Package for Social Sciences (SPSS) version 20 (IBM SPSS Statistics 20) was used for both data entry and analysis.

RESULTS

A total of 439 patients had undergone VP shunt placement at our hospital during the period of this study. These consisted of 319 adult and 120 pediatric cases respectively. Amongst these patients, 67 (52 adult and 15 pediatric cases) had post-cranial surgery as the etiology of hydrocephalus and thus were included in the final analysis (Figure 1).

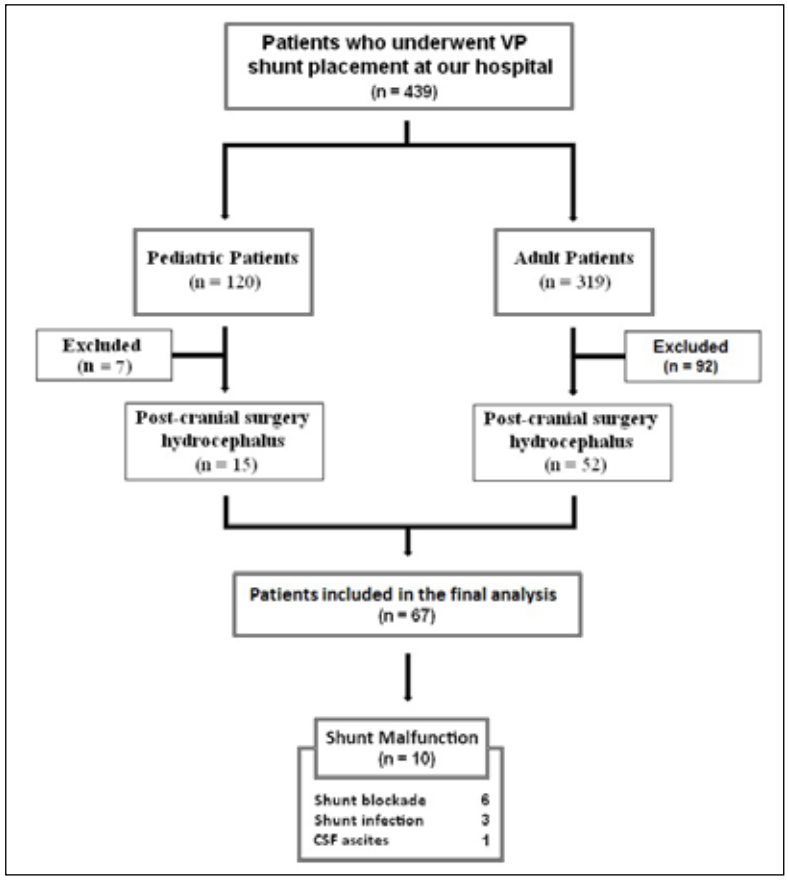

Figure 1: Flow diagram illustrating the inclusion and exclusion of both adult and pediatric patients for inclusion in the final analysis of this study.

Patient Demographics

The mean age of all patients (n = 67) was 32.2 years. More specifically, the mean age for pediatric patients (n = 15) was 7.7 years (7 months to 15 years). For adult patients (n = 52), the mean age was 39.3 years (17 to 71 years). Almost two-third (n = 43, 64.2%) of our patients were male.

Amongst the adult patients (n = 52), only five patients (9.6%) had hypertension, while diabetes mellitus was noted in only one patient (1.9%). Amongst the pediatric patients (n = 15), five patients (33.3%) had spontaneous vaginal delivery, two (13.3%) were born via Caesarean section and data was missing for the remaining patients (n = 8, 53.3%). Six pediatric patients (40%) were born full-term, while data was missing for the remaining 7 patients (60%). This is summarized in Table I.

Past History and Clinical Features

A review of the past medical history of patients revealed that 28 patients (46.3%) had a history of brain tumor resection. The most common types of brain tumors included astrocytoma (n = 6, 21.4%), medulloblastoma (n = 4, 14.3%) and meningioma (n = 4, 14.3%). The most common location for these brain tumors was the posterior fossa (n = 10, 35.7%). Amongst the pediatric patients (n = 15), two patients (13.3%) had a history of encephalocele repair. Other details regarding the past medical history of our study subjects is summarized in Table II.

The most common symptoms of patients included in our study were headache (n = 24, 35.8%), altered consciousness or drowsiness (n = 23, 34.3%), gait disturbances (n = 19, 28.4%), nausea or vomiting (n = 16, 23.9%), fever (n = 10, 14.9%), urinary or fecal incontinence (n = 10, 14.9%) and weakness (n = 10, 14.9%). The initial physical examination performed

Table I: Demographics of Patients Included in Our Study (n = 67)

Characteristics	N (%)
Sex	
Male	43 (64.2%)
Female	24 (35.8%)
Age	
Mean age for all patients (n = 67)	32.2 years
Mean age for pediatric patients (n = 15)	7.7 years
Mean age for adult* patients (n = 52)	39.3 years
Infants and young children (<5 years)	6 (8.9%)
Older children (5-16 years)	9 (13.4%)
Younger adults (16-40 years)	29 (43.3%)
Middle-aged (40-65 years)	16 (23.9%)
Elderly (>65 years)	3 (4.5%)
Mode of delivery for pediatric patients (n =15)	
Vaginal delivery	5 (33.3%)
Caesarean delivery	2 (13.3%)
Missing data	8 (53.3%)
Maturity at birth for pediatric patients (n = 15)	
Full term	6 (40.0%)
Missing data	7 (60.0%)
Co-morbidities of adult patients (n = 52)	
Hypertension	5 (9.6%)
Diabetes mellitus	1 (1.9%)

** In this study, all patients aged 16 years or more were considered as "adults."*

Table II: Past Medical and Surgical History of Patients (n = 67)

Past history	N (%)
Congenital abnormalities in pediatric patients (n = 15)	
Encephalocele	2 (13.3%)
Arnold-Chiari malformation	1 (6.7%)
Brain tumors	28 (46.3%)
Traumatic brain injury	8 (11.9%)
Types of brain tumors (n = 28)	
Astrocytoma	6 (21.4%)
Medulloblastoma	4 (14.3%)
Meningioma	4 (14.3%)
Oligodendroglioma	2 (7.1%)
Craniopharyngioma	2 (7.1%)
Hemangioblastoma	2 (7.1%)
Ependymoma	2 (7.1%)
Dermoid tumors	2 (7.1%)
Glioblastoma multiforme	1 (3.6%)
Pinealoblastoma	1 (3.6%)
Central neurocytoma	1 (3.6%)
Schwannoma	1 (3.6%)
Locations of brain tumors (n = 28)	
Posterior fossa	11 (39.3%)
Cerebellopontine angle	4 (14.3%)
Lateral ventricle	4 (14.3%)
Frontal lobe	4 (14.3%)
Middle fossa	3 (10.7%)
Para- or suprasellar	1 (3.6%)
Fourth ventricle	1 (3.6%)

on these patients revealed that the mean and median GCS at presentation was 13 and 14 respectively. Three (4.5%) patients were comatose (GCS ≤ 8) on presentation, while another 23 patients (34.3%) had motor deficits (Table III).

Laboratory work-up of our patients included serum chemistry, blood counts, blood culture and radiologic investigations. Lumbar puncture was performed in 40 patients (59.7%) and further details are provided in Table III.

Management

The mean and median duration of hospital stay for our patients was 11.7 days and five days respectively. Antibiotics were administered to 61 (91.0%) patients and most of these patients (n = 52, 85.2%) received antibiotics for a period of one week or less. Mannitol was administered to six patients (8.9%), steroids and anti-convulsants were required in 12 (17.9%) and 20 (29.9%) patients respectively. All patients included in the study underwent VP shunt placement. A right-sided VP shunt was inserted in 45 (67.2%) patients, while external ventricular drains were placed in 49 (73.1%) patients, prior to placement of VP shunt. These results are summarized in Table IV.

Clinical Follow-Up

Regular outpatient follow up was noted in 55 (82.1%) patients for a mean duration of 485.4 days. The remaining patients (n = 12, 17.9%) followed up for only one or two clinic visits following VP shunt placement. Amongst the patients who followed up regularly (n = 55), the most common complaints reported by the patients were headache (n = 6, 10.9%), drowsiness or alteration in consciousness (n = 2, 3.6%) and seizures (n = 2, 3.6%). New-onset cognitive and visual deficits were noted in two (3.6%) and four (7.2%) patients respectively. The median Karnofsky Performance Status (KPS) score of patients who followed up regularly (n = 55) was 70 (Table IV). Among the study subjects included in this study, only one (1.5%) pediatric patient (aged 4 years) died in the immediate post-operative period.

Shunt Complications

The overall rate of shunt failure noted in our study was 14.9% (n=10). Shunt revision was performed in all of these cases. Blockade was the most common cause of shunt failure (n = 6, 60%) followed by infection (n = 3, 30%) and CSF ascites (n = 1, 10%). The characteristics of patients who suffered shunt failure in our study are given in Table V. Using Kaplan-Meier survival analysis, the shunt failure rate at one month and six months was calculated to be 8.9% and 13.4% respectively. The shunt failure rate among adult (n = 52) and pediatric patients (n = 15) was 13.5% and 20% respectively. However, the difference was not statistically significant (p = 0.531). No statistically significant difference was noted in the shunt failure rate between male and female patients (p = 0.677), those with a history of brain tumor (p = 0.412) or those with a history of traumatic brain injury (p = 0.837).

Factor Affecting Time to First Shunt Failure (VP Shunt Survival)

The median time from shunt placement to shunt failure was 22.5 days ranging from one to 243 days (Figure 2). As given in Figure 3, Kaplan-Meier plot showed that the median time to first shunt failure was significantly less for patients who developed hydrocephalus following cranial surgery for brain

Table III: Clinical Features of Study Subjects (n = 67)

Subjective symptoms	**N (%)**
Headache	24 (35.8%)
Drowsiness or altered consciousness	23 (34.3%)
Gait disturbances	19 (28.4%)
Nausea and vomiting	16 (23.9%)
Urinary or fecal incontinence	10 (14.9%)
Weakness	10 (14.9%)
Fever	10 (14.9%)
Vision disturbances	4 (6.0%)
Unusual increase in head size	4 (6.0%)
Seizures	4 (6.0%)
Confusion	3 (4.5%)
Findings on physical examination	**N (%)**
Tachycardia (on presentation)	5 (7.5%)
Glasgow coma scale (on presentation)	
Mean GCS	13
Median GCS	14
Comatose patients (GCS ≤ 8)	3 (4.5%)
Motor deficits on presentation	23 (34.3%)
Laboratory and radiologic data	**N (%)**
Lumbar puncture	40 (59.7%)
Findings on CSF examination (n = 40)	
Normal findings	23 (57.5%)
CSF pleocytosis or hypoglycorrhachia	10 (25.0%)
Other abnormalities	3 (7.5%)
Missing data	4 (10.0%)
Findings of CSF culture (n = 40)	
No growth	29 (80.6%)
Missing data	3 (7.5%)
Positive culture	7 (19.4%)
Type of pathogen (n = 7)	
Gram negative rods	5 (71.4%)
Gram positive cocci	2 (28.6%)

CSF: *Cerebrospinal fluid,* ***GCS:*** *Glasgow Coma Scale.*

tumors as compared to others (p = 0.019, Log Rank). The type (p = 0.317, Log Rank) or location (p = 0.273, Log Rank) of brain tumor did not have a significant impact on the median time to first shunt failure. Moreover, there was no statistically significant difference in the median time to first shunt failure between pediatric and adult patients (p = 0.365, Log Rank), or between male and female patients (p = 0.868, Log Rank). Time to first shunt failure was also not significantly different among patients of different age groups (p = 0.620, Log Rank).

In our study, median shunt survival time was found to be significantly different between patients who had received antibiotics for a duration of one week or less and those who had received antibiotics for longer periods (p = 0.018, Log Rank) (Figure 4). Furthermore, as given in Figure 5, shunt survival was particularly worse in patients who were administered steroids as part of their in-hospital management compared to those who were not administered steroids (p = 0.004, Log Rank). The difference in the median time to first shunt failure among

Table IV: Medical and Surgical Aspects of Management and Findings on Follow-up (n = 67)

Medical management	**N (%)**	**Surgical management**	**N (%)**
Median duration of stay	5 days	Ventriculoperitoneal shunt	67 (100%)
Antibiotics	61 (91.0%)	*Side of shunt* (n = 67)	
Mannitol	6 (8.9%)	Right-sided VP shunt	45 (67.2%)
Acetazolamide	2 (3.0%)	Left-sided VP shunt	22 (32.8%)
Anticonvulsants	20 (29.9%)	Extra-ventricular drains	49 (73.1%)
Steroids	12 (17.9%)	Post-operative physiotherapy	27 (23.9%)
Duration of antibiotic therapy (n = 61)			
Up to one week	52 (85.2%)		
More than one week	9 (14.8%)		
Clinical follow-up		**N (%)**	
Patients who followed up regularly		55 (82.1%)	
Patients lost to follow up		12 (17.9%)	
Mean duration of follow up		485.4 days	
Subjective complaints (n = 55)			
Headache		6 (10.9%)	
Drowsiness or altered consciousness		2 (3.6%)	
Seizures		2 (3.6%)	
Nausea or vomiting		2 (3.6%)	
Vision disturbances		1 (1.8%)	
Urinary or fecal incontinence		1 (1.8%)	
Neurologic examination findings (n = 55)			
New-onset visual deficits		2 (3.6%)	
New-onset cognitive deficits		4 (7.2%)	
Wound examination (n = 55)			
Healthy wounds		49 (89.1%)	
Missing data		6 (10.9%)	
Karnofsky Performance Status (n = 55)			
Median score		70	

VP shunt: *Ventriculoperitoneal shunt.*

patients who had received anti-convulsants (p = 0.121) or mannitol (p = 0.267) failed to reach statistical significance. The placement of external-ventricular drains was also not noted to have any statistically significant influence on VP shunt survival (p = 0.237, Log Rank).

■ DISCUSSION

VP shunt insertion has remained the most popular method for treatment of hydrocephalus in adults (17). A few additions have also been made to the list of available treatment options with the most noteworthy being endoscopic third ventriculostomy (ETV) (20). However, this method is preferred mainly in non-communicating hydrocephalus (15, 18, 23). In patients with hydrocephalus secondary to infective etiologies (4, 6, 21, 31) or meningomyelocele (4, 11, 48) as well as in neonates and infants (4, 15, 18, 48, 50), the effectiveness of ETV remains questionable. Thus VP shunt placement continues to be an important corner-stone in the management of hydrocephalus in both adult and pediatric patients.

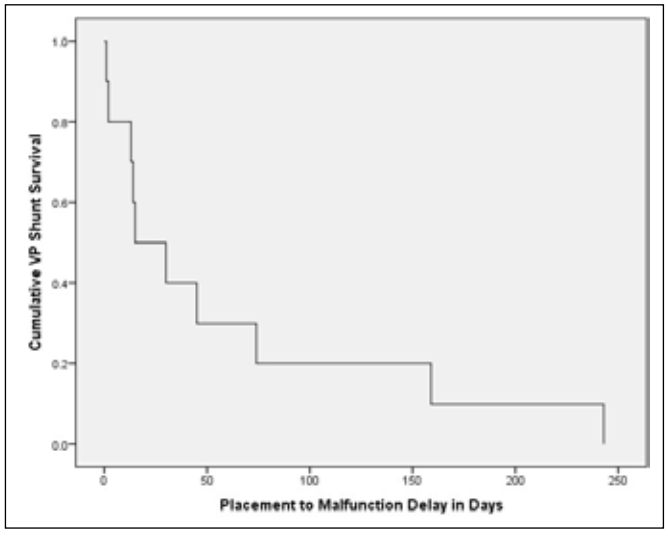

Figure 2: Kaplan-Meier shunt survival analysis for post-cranial surgery hydrocephalus shows overall median time to first shunt failure was 22.5 days with shunt survival time ranging from a minimum of one day to a maximum of 243 days.

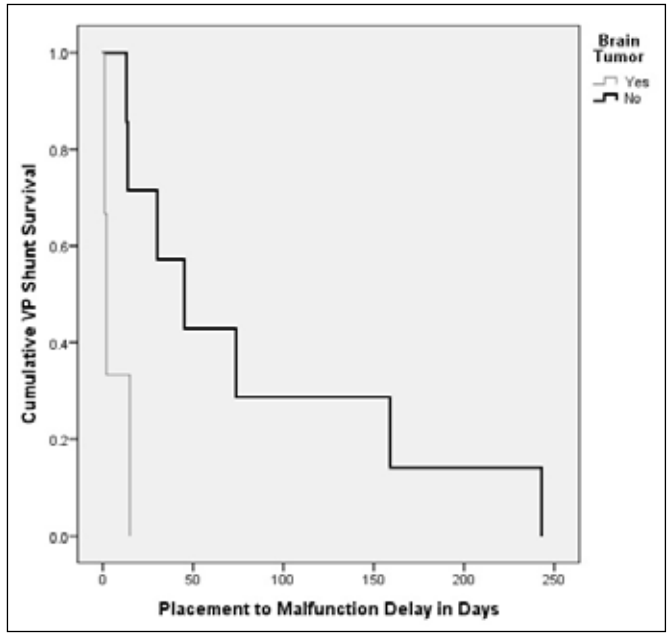

Figure 3: Kaplan-Meier shunt survival analysis shows worse shunt survival in patients developing hydrocephalus following cranial surgery performed for brain tumors (p = 0.019, Log Rank).

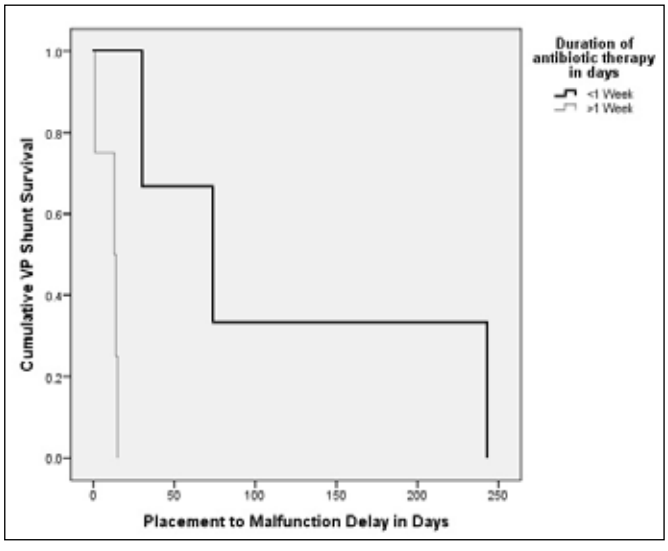

Figure 4: Kaplan-Meier shunt survival analysis for post-cranial surgery hydrocephalus shows that patients who had received antibiotics for a duration of greater than one week had significantly reduced shunt survival (p = 0.018, Log Rank).

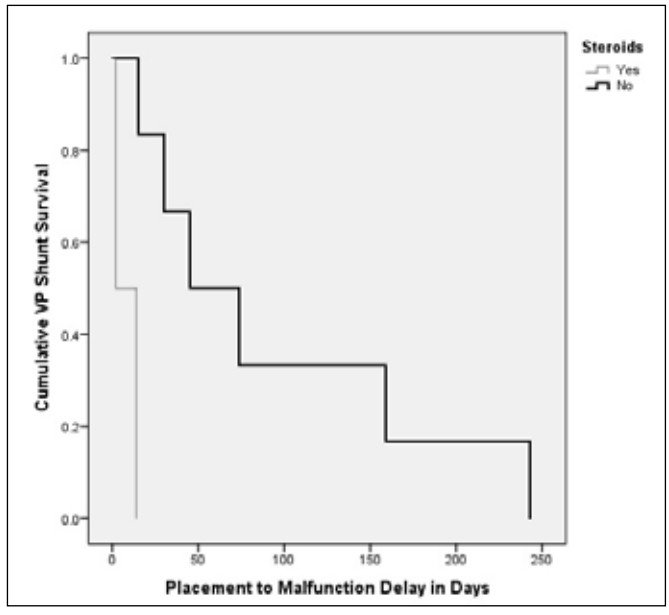

Figure 5: Kaplan-Meier shunt survival analysis for post-cranial surgery hydrocephalus showing the adverse impact of steroids on the median time to first shunt failure (p = 0.004, Log Rank).

Table V: Details of Patients Who Experienced Shunt Failure in Our Study (n = 10)

No	Type of shunt malfunction	Placement to shunt failure time (days)	History of brain tumor	Antibiotic therapy	Steroids administered
1.	Shunt blockade	1	Schwannoma at left CP angle	More than one week	No
2.	Shunt blockade	2	Ependymoma of lateral ventricle	--	Yes
3.	Shunt blockade	13	--	More than one week	No
4.	Shunt infection	14	--	More than one week	Yes
5.	Shunt blockade	15	Suprasellar craniopharyngioma	More than one week	No
6.	Shunt infection	30	--	Less than one week	No
7.	CSF ascites	45	--	--	No
8.	Shunt blockade	74	--	Less than one week	No
9.	Shunt infection	159	--	--	No
10.	Shunt blockade	243	--	Less than one week	No

CP angle: *Cerebellopontine angle.*

Multiple studies have reported the impact of etiology of hydrocephalus on VP shunt survival in both adult and pediatric patients (26, 27, 44, 49, 51). In the present retrospective file review, we specifically studied patients who had developed hydrocephalus following cranial surgery and subsequently underwent VP shunt insertion. The impact of various factors like patient demographics, past medical history and in-patient management on shunt survival was analyzed. Follow-up of patients in neurosurgery clinics were also reviewed to determine performance status and the development of any new complaints.

The VP shunt failure rate observed in our study for post-cranial surgery hydrocephalus was 14.9%. This is considerably lower than the overall VP shunt failure rate (inclusive of all etiologies) reported by previous studies from other parts of the world (25, 30, 34, 35, 49, 51). However, the shunt failure rate observed in our study is in line with more recent reports published in the literature, even from the developing world (12, 14).

The shunt failure rate for pediatric patients (20%) included in our study was slightly higher than that for adult patients (13.5%), although the difference failed to reach statistical significance. This may be explained by the technical difficulties encountered in both the surgical and medical management of such patients (27, 44, 49). Other demographic factors like sex, age and co-morbid conditions did not influence the frequency of shunt failure in this study. A predominance of male patients (64.2%) was noted in our study and is in accordance with a previous report from our own hospital (38). This trend has also been noted in other studies from the developing world (12,24). Gender as an independent risk factor for shunt failure remains unsettled (12, 49, 51). Moreover, previous studies failed to show a significant impact of patient's age on VP shunt failure (51). However, neonates and infants were noted to have a higher rate of shunt failure in the report by Di Rocco et al (7).

The median time from shunt placement to first shunt failure noted in our study was 22.5 days, which is comparable to that reported by other studies (12, 14). As mentioned previously, the development of hydrocephalus following cranial surgery (29) may be attributed to the direct collateral damage incurred during the surgical procedure (19). Theoretically, therefore, the indication for which cranial surgery was performed, the expertise of the operating surgeon, the surgical techniques employed as well as other patient factors may influence the survival of VP shunts placed in such patients. In our study, patients who developed hydrocephalus following cranial surgery performed for brain tumors had a significantly decreased median time to first shunt failure. This may be explained by the extensive manipulation and injury to tissues incurred during resection of neoplastic disease as well as the alterations in cerebral blood flow and auto-regulation that develops after the procedure (19, 29, 46, 47).

An interesting finding noted in our study was that patients who had received steroids as part of their in-patient management had worse shunt survival. Corticosteroids are often employed in the initial management of patients with brain tumors (1, 42), tuberculous meningitis (43) and other infections like neurocysticercosis (41). In our study, corticosteroids were employed in the management of 12 patients, out of which two patients developed shunt failure. However, the placement to malfunction time in both these patients (two days and 14 days) was much shorter than that of other patients with shunt failure, who were not on steroids (median of 59.5 days). The benefit of long-term steroid therapy in hydrocephalus secondary to infectious etiologies has been reported in a few studies (41). However, Foley et al. (10) reported the worsening of hydrocephalus after treatment with corticosteroids in a patient with neurosarcoidosis. Steroids may possibly worsen shunt survival by down-regulating the process of protein expression within fibroblasts leading to inhibition of anabolic processes. (2, 14) This can hinder the process of healing and granulation

tissue formation, with subsequent risk of dehiscence of skin, subcutaneous tissue and meningeal layers. (2, 14) The impact of steroids on the shunt survival time in patients developing hydrocephalus following cranial surgery requires further evaluation through larger prospective studies.

Another intriguing finding noted in our study was that patients who received prolonged antibiotic therapy were more likely to experience early shunt failure. While the role of short-term prophylactic antibiotics in neurosurgery is well-established (9), many studies have also shown that prolonged use of antibiotics can promote anti-microbial resistance and serve as a means of "natural selection" for more virulent pathogens (8). Infection with such organisms can prove to be detrimental for shunt survival (5, 16, 36). Additionally, some evidence also suggests that prolonged use of antibiotics can impair the natural process of suppurative inflammation and result in the formation of conglomerate micro-abscesses (25). These can impede CSF flow through the shunt system, ultimately culminating in VP shunt failure.

Our study was subject to a number of limitations, which must be kept in mind before reaching a conclusion. As mentioned before, hydrocephalus developing after cranial surgery is intimately related to the surgical procedure itself. At our hospital, surgical procedures were performed by seven different neurosurgeons. However, in the present study, we did not compare the shunt failure rate among different neurosurgeons. Moreover, shunt devices and preference of surgical methods were not analyzed separately. Only a single type of shunt was placed in all patients included in our study and therefore, the influence of the type of shunt on subsequent shunt survival could not be assessed. Among the patients included in the study, a small proportion of patients did not follow-up regularly after the surgical procedure, which may have led to under-detection of delayed shunt complications. Lastly, a substantial number of patients who had undergone VP shunt placement at our hospital were excluded from the analysis due to unavailability of medical records and missing data. This may have resulted in possible selection bias.

Despite the limitations of this being a retrospective study, it bears significant value as it is one of the few studies to assess shunt failure in patients with post-cranial surgery hydrocephalus. Hydrocephalus developing after cranial surgery represents a unique subset of patients with hydrocephalus and little is known about the determinants of shunt failure in these patients. Our study sheds some light on VP shunt survival in such patients and may provide a direction for future research. The association of steroid therapy with worsened shunt survival observed in our study needs to be explored further through larger prospective studies.

CONCLUSION

Post-cranial surgery hydrocephalus represents a unique subset of hydrocephalus. Patients who developed hydrocephalus following cranial surgery performed for brain tumors had worse shunt survival. Moreover, patients who had received antibiotics for more than one week and those who had been administered steroids were also at high risk of early shunt failure. Further studies are needed to accurately characterize and elucidate the mechanism of this deleterious impact of steroids on shunt survival in this particular group of patients.

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