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Factors Causing Shunt Malfunction in Pediatric Age Group

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[1,2]Substantial contributions to the conception or design of the work; or the acquisition, [4,6]Active participation in active methodology, [2,3]analysis, or interpretation of data for the work, [5]Drafting the work or revising it critically for important intellectual content

Funding Source: None
Conflict of Interest: None

Received: Sept 15, 2024
Accepted: Dec 27, 2024

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ABSTRACT

Objective: To find out factors causing shunt malfunction among pediatric patients.

Methodology: A Cross-sectional observational study, was conducted at Department of Neurosurgery at Pakistan Institute of Medical Sciences, Islamabad. Patients aged between 1st day of life to 12 years, both gender and raised Intra cranial pressure (ICP) requiring VP shunt placement were included. The patients were followed in the post-operative period till discharge. Shunt malfunction was defined as any condition which compromises the shunt function and requires revision surgery or intervention to correct the shunt function. Data was collected according to self-structured questionnaire and analysis was done on SPSS version 26.

Results: Mean age of the patients was 24.29±36.12 months. Males were 84(60.0%) and females were 56(40.0%). Frequency of shunt malfunction was seen in 26(18.60%) of the cases and the most common causative factor was valve malfunction (19.2%), followed by displacement and central nervous system (CNS) infections (each 15.4%). Other causes included proximal catheter obstruction (11.5%), skin infections, and distal catheter obstructions (each 7.7%). Malfunctions occurred most frequently within two weeks post-operation (53.8%). Furthermore, the frequencies of factors responsible, for shunt malfunction were statistically insignificant according to age and gender (p->0.05).

Conclusion: The study revealed that 18.60% of pediatric cases experienced shunt malfunction, primarily due to valve malfunction, displacement, central nervous system infections, and catheter obstructions, with most malfunctions occurring within two weeks post-operation.

Keywords: VP shunt, malfunctions, incidence, factors.

Cite this article as: Khudeja, Rehman L, Hamdani M, Khan MA, Aslam S, Jamil SR. Factors Causing Shunt Malfunction in Pediatric Age Group. Ann Pak Inst Med Sci. 2025; 21(1):307-311. doi. 10.48036/apims.v21i1.700

Introduction

Hydrocephalus is among the most frequently occurring neurosurgical conditions affecting children throughout the world, that requires require surgical treatment and lifelong follow up and care. The worldwide occurrence of hydrocephalus among children is reported in various studies to affect nearly one out of every 1000 live births, with rates being markedly greater in low- and middle-income countries.[1,2] Pediatric hydrocephalus is generally classified into two main types: congenital and acquired. In infants, hydrocephalus typically manifests as a progressive enlargement of head circumference, while in older children it usually presents with symptoms and signs of raised intracranial pressure.[3] The clinical manifestation of raised intra cranial pressure among include papilledema, recurrent vomiting, excessive lethargy, and persistent headache, particularly in older children. These signs should raise suspicion for raised ICP so that it can be diagnosed and treated early which leads to better outcome. Evaluation of the ventricles through computed tomography (CT) and magnetic resonance imaging (MRI) has become a standard practice in the diagnosis and management of hydrocephalus.[4] Depending upon the underlying pathology raised ICP can be treated either by medical or surgical intervention or both. A ventriculoperitoneal shunt (VPS) is one of the most frequently performed procedures for managing

hydrocephalus, a neurological condition caused by either excessive production or impaired absorption of cerebrospinal fluid. However, VP shunt like any other surgical procedure has its own complications which shunt malfunction being a lethal one.[5] Shunt malfunction leads to raised ICP and hence causing neurological damage. There can be a number of factors which can cause shunt malfunction. If they can be identified then shunt malfunction can be avoided. However, till date very limited literature is available regarding factors causing shunt malfunction. In a study conducted it was found that majority of the shunt malfunction was not associated with infection. Overall shunt malfunction rate was 26.7%. Other factors that were associated with shunt malfunction were longer duration of surgery, emergency surgery and less experience of the surgeon.[6] Similarly in another study conducted it was found that every 5th shunt was associated with some complication with shunt malfunction occurring in 7.3% of the cases.[7] In another study about 42.71% had shunt related complications but they failed to identify the factors associated with shunt malfunction.[8] In another study it was found that age <1 years and those having infectious complications had greater risk of shunt malfunction.[9] In another study almost all of the pediatric patients required shunt revision because of shunt malfunction.[10] After taking above controversial findings, this study aimed to identify the incidence of shunt malfunction and various mechanical vs non mechanical factors associated with shunt malfunction in pediatric population.

Methodology

A cross-Sectional observational study was conducted at Department of Neurosurgery at Pakistan Institute of Medical Sciences, Islamabad. After CPSP approval, the study was done over 8 months from October 2023 to May 2024 at department of neurosurgery. The ethical approval was also taken by from ethical review board of PIMS ref no F-5-2/2024(ERRB)/PIMS. Sample size of 139 patients was calculated using WHO calculator, with confidence level of 95% and anticipated population: 0.1, Precision: 0.05. Simple convenient consecutive sampling technique was used. All the patients aged between 1st day of life to 12 years, both gender and raised ICP requiring VP shunt placement were included. Patients with intraoperative complications, VP shunt placement in the past, immunodeficiency and abdominal pathology increasing the risk of shunt failure were excluded. VP shunt was defined as a technique where a device is inserted connecting brain ventricles to peritoneal cavity so that CSF can be drained ICP can reduced. The patient fulfilling the inclusion criteria were enrolled in the study and followed in the post-operative period till discharge. Shunt malfunction was defined as any condition which compromises the shunt function and requires revision surgery or intervention to correct the shunt function. Data was collected according to self-structured questionnaire. Mechanical and non-mechanical factors causing shunt malfunction will be identified. All the data was entered and analyzed on SPSS version 26. Quantitative data such as age, duration of surgery was presented as mean and standard deviation. Frequency of categorical data such gender and shunt malfunction factors were calculated. Chi square test was used to find association between different factors and shunt malfunction by taking a p-value $\leq$0.05 as significant.

Results

Mean age of the patients was 24.29$\pm$36.12 months. Males were 84(60.0%) and females were 56(40.0%). The most common underlying pathology was congenital hydrocephalus (HCP), in 58.6% of cases, followed by post-meningitis hydrocephalus 16.4%, posterior fossa space-occupying lesions (10.7%), intraventricular space-occupying lesions (4.3%), and post-traumatic hydrocephalus (3.6%). Less frequent pathologies were craniopharyngioma, post-meningitis myelomeningocele (mmc) repair HCP, Sellar and suprasellar space-occupying lesions, each comprising less than 2% of the cases. Table: 1.

Table I: Underlying pathological indication for VP shunt placement. (n=140)

Underlying pathology	Frequency	Percent
Congenital HCP	82	58.6
Craniopharyngioma	01	0.7
Intraventricular SOL	06	4.3
Post meningitis HCP	23	16.4
Post mmc repair HCP	01	0.7
Post traumatic HCP	05	3.6
Post traumatic SAH + HCP	01	0.7
Post-mmc repair HCP	02	1.4
posterior fossa SOL	15	10.7
Sellar + suprasellar SOL	02	1.4
Sellar SOL	02	1.4
Total	140	100.0

Frequency of shunt malfunction was seen in 26(18.60%) of the cases as shown in figure 1.

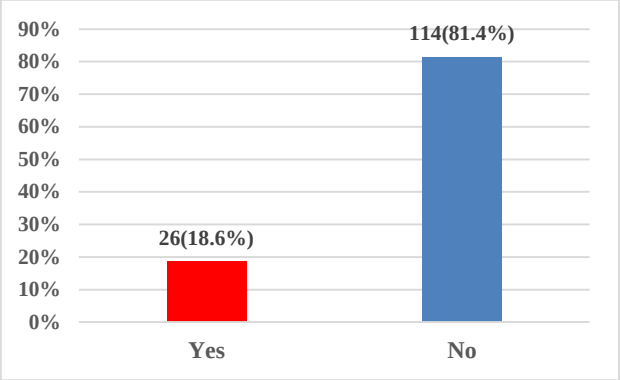

Figure 1. Frequency of shunt malfunction. (n=140)

The most common causative factor was valve malfunction (19.2%), followed by displacement and central nervous system (CNS) infections (each 15.4%). Other causes included proximal catheter obstruction (11.5%), skin infections, and distal catheter obstructions (each 7.7%). Malfunctions occurred most frequently within two weeks post-operation (53.8%). The majority of patients required only one revision surgery (76.9%), with fewer needing two (15.4%) or five (7.7%) revisions.

Table II: Causative factors of VP shunt malfunction, its post-operative day and number of revision surgeries. (n= 26)

Variables	Frequency	%
Causative factors		
Valve Malfunction	5	19.2
Displacement	4	15.4
Blood clot	1	3.8
CNS infection	4	15.4
Skin infection	2	7.7
Proximal catheter obstruction	3	11.5
Distal catheter obstruction	2	7.7
Valve Malfunction+ displacement	1	3.8
Valve Malfunction + blood clot	1	3.8
Proximal catheter obstruction and displacement	1	3.8
Valve Malfunction + blood clot and Proximal catheter obstruction	1	3.8
Valve Malfunction and skin infection	1	3.8
Total	26	100.0
POD on which shunt malfunction occurred		
1 day	2	7.7
2 days	1	3.8
2 weeks	14	53.8
3 weeks	1	3.8
1 month	1	3.8
6 months	3	11.5
1 year	1	3.8
2 years	1	3.8
3 years	2	7.7
Total	26	100.0
Number of revision surgery		
I	20	76.9
II	4	15.4
V	2	7.7
Total	26	100.0

Table II.

Furthermore, the frequency of factors responsible for shunt malfunction was statistically insignificant according to age and gender (p->0.05). Table: 3.

Discussion

Hydrocephalus remains one of the most prevalent neurological conditions requiring surgical intervention, particularly in pediatric populations. This study found a mean age of 24.29 ± 36.12 months, reflecting the early onset of the condition, consistent with global and regional data emphasizing hydrocephalus as a predominant disorder in infancy and early childhood. A male predominance (60%) was also noted, which aligns with several studies, including a retrospective analysis by Rasool et al[11], where males accounted for 63% of hydrocephalus cases, suggesting possible sex-related vulnerability or differential access to care. Additionally we found the most common underlying pathology identified was congenital hydrocephalus (58.6%), followed by post-meningitis hydrocephalus (16.4%). This trend is corroborated by studies from both Asia and Pakistan. For instance, a multicenter study by Wu et al[12] reported congenital causes as the leading etiology of pediatric hydrocephalus, accounting for over 50% of cases. In Pakistan, Ahmed et al[13] found congenital hydrocephalus in 55% of their pediatric cohort, with post-infectious causes such as meningitis contributing 20%. The high rate of congenital hydrocephalus may reflect improved antenatal diagnostics and referral systems, but it also highlights persistent challenges related to prenatal care and genetic counseling, particularly in low- and middle-income countries. Other identified causes like posterior fossa lesions (10.7%), intraventricular tumors (4.3%), and post-traumatic hydrocephalus (3.6%) were less common, yet they align with tertiary care neurosurgical center reports. A study from India by Singh et al[14] similarly reported tumor-related hydrocephalus in 12% of cases, suggesting that neoplastic etiologies, although less common, remain significant due to their complex management. Furthermore, rare causes such as craniopharyngioma and myelomeningocele-associated hydrocephalus (each <2%) are indicative of the varied and multifactorial nature of hydrocephalus, warranting individualized care.

Table III: Factor responsible for shunt malfunction according to age and gender. (n= 26)

	Gender			Age groups		
Factor	**Male**	**Female**	**p-value**	**1-3 years**	**3- 5 or >5 years**	**p-value**
Valve Malfunction	3(11.5%)	2(7.7%)		2(7.7%)	3(11.5%)	
Displacement	2(7.7%)	2(7.7%)		2(7.7%)	2(7.7%)	
Blood clot	1(3.8%)	--		1(3.8%)	--	
CNS infection	2(7.7%)	2(7.7%)		4(15.4%)	--	
Skin infection	2(7.7%)	--		2(7.7%)	--	
Proximal catheter obstruction	--	3(11.5%)		1(3.8%)	2(7.7%)	0.381
Distal catheter obstruction	--	2(7.7%)	0.280	1(3.8%)	1(3.8%)	
VM+ displacement	1(3.8%)	--		1(3.8%)	--	
Valve Malfunction + blood clot	1(3.8%)	--		1(3.8%)	--	
PCO and displacement	--	1(3.8%)		--	1(3.8%)	
VM + blood clot and PCO	--	1(3.8%)		--	1(3.8%)	
VM and skin infection	1(3.8%)	--		1(3.8%)	--	

In this study the shunt malfunction rate (18.6%) in this study falls within the acceptable range reported in the literature, although slightly lower than figures in some regional studies. In a study conducted at Lahore General Hospital, Khalid et al[15] reported a 22.5% malfunction rate within the first year post-VP shunting. Shunt-related complications remain a formidable challenge due to the mechanical nature of the devices and the susceptibility to infection in pediatric patients.

In this study among the malfunction causes, valve dysfunction (19.2%) was most frequent, followed by displacement and CNS infections (15.4% each). This distribution is consistent with a report by Al-Nuaimi et al[16] from Iraq, where valve-related issues were the leading cause of early shunt failure. Similarly, other studies have noted infections and mechanical complications as key contributors, often exacerbated by late diagnosis or inadequate post-operative care, like Nawaz et al[17] documented CNS infections as a leading factor due to environmental factors and compromised surgical sterility in resource-limited settings. However 53.8% of malfunctions occurred within the first two weeks post-operatively, emphasizing the need for vigilant early monitoring. This early complication trend is supported by an Indian study by Dey et al[18] who found that more than half of shunt malfunctions occurred within the initial month, typically due to technical issues or infection. Interestingly, in this stuffy most patients required only one revision surgery (76.9%), indicating relatively effective initial management. While some studies report multiple revisions in up to 30% of cases, the lower revision rates in this cohort may reflect improved surgical techniques or better follow-up protocols. Furthermore in this study the lack of statistical significance between shunt malfunction and patient age or gender ($p > 0.05$) suggests that mechanical and biological factors influencing shunt performance are relatively independent of these demographic parameters. This finding is mirrored in studies by Gul et al[19] and Kumar et al[20], which found no consistent correlation between age, gender, and shunt outcomes, reinforcing the notion that individualized surgical care and infection control protocols are more pivotal determinants of prognosis. Overall the findings underscore the predominance of congenital hydrocephalus in pediatric patients and highlight the significance of early post-operative surveillance to address complications. Although shunt malfunctions are not uncommon, timely identification and revision can significantly reduce morbidity. Regional patterns, including those in Pakistan and other parts of Asia, reflect shared challenges in neurosurgical care delivery, yet also demonstrate the evolving success of targeted interventions.

Conclusion

It has been concluded that the shunt malfunction occurred in 18.60% of pediatric cases, with valve malfunction being the leading cause including displacement, central nervous system infections, and both proximal and distal catheter obstructions. It was observed that the majority of these malfunctions took place within two weeks post-operation, emphasizing the critical need for close monitoring during this period.

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