Egyptian Journal of Neurosurgery

RESEARCH Open Access

Mechanical shunt failure in hydrocephalus: a common but remediable complication with technical nuances

Mohsin Fayaz[1*], Azhar Khalid[1], Abrar Ahad Wani[1] and Sajad Hussain Arif[1]

Abstract

Background A ventriculoperitoneal (VP) shunt is a cerebral shunt that diverts excess cerebrospinal fluid (CSF). Obstruction in the normal outflow or decreased absorption of the fluid is the usual cause. Hydrocephalus is treated by cerebral shunts.In paediatric patients, untreated hydrocephalus can be lethal and leads to many adverse effects including increase irritabilities, chronic headaches, learning difficulties, visual disturbances, and, in more advanced cases, severe mental retardation. Malfunction of the shunt with excess CSF accumulated can increase the intracranial pressure resulting in cerebral oedema and ultimately herniation.

Objective To study and evaluate the mechanical causes of shunt failure and their surgical remedies and reduce the preventable morbidity, cost and mortality associated with shunt failure.

Methods We conducted a prospective observational study including 70 patients who developed pure mechanical shunt failure for the first time from 2017 to 2020 in the Department of Neurosurgery Sher-i-kashmir Institute of Medical Sciences. Patients with previous shunt surgeries which include VP shunting and shunt revision or failure and shunt infections were excluded. Identity of all the patients has been kept anonymus. Written informed consent was obtained from all patients or their guardians in case of minors. Shunt malfunction was in the form of catheter misplacement, kinking, displacement from the ventricle or peritoneal cavity, disconnection, migration,inadvertent suturing of the catheter, air in shunt bulb.

Results We found kinking at the proximal end in 25 (35%) patients as the most common cause of shunt failure. It was mostly as a result of inadequate and less spacious tunnelling made for the reservoir. Inadvertant suturing of shunt while closing abdomen in 7 (10%), shunt disconnection in 6 (8.5%), air in shunt bulb in 2 (2.8%), wrong placement at ventricular end in 10 (14.2%), shunt migration into the brain parenchyma in 5 (7.1%), shunt migration through the anal canal in 1(1.4%), pseudomeningocele around catheter valve in 3 (4.2%), placement of lower end into the preperitoneal space in 4 (5.7%) patients.

Conclusions Shunt surgery is seemingly a straightforward operation for neurosurgeons. But considering the incidence of shunt failure and its associated morbidity and mortality, it should always be done with trepidation and extreme caution. Exclusive mechanical shunt malfunction is a major concern and leads to great deal of morbidity in the shunt operations. However, there are trivial remedies and technical nuances which needs to be followed during surgery to avoid these complications.

Keywords Mechanical, Shunt, Hydrocephalus, Failure

*Correspondence:
Mohsin Fayaz
mohsin.fayaz.bhat@gmail.com
Full list of author information is available at the end of the article

Introduction

A ventriculoperitoneal (VP) shunt is a cerebral shunt that diverts excess cerebrospinal fluid (CSF). Obstruction in the normal outflow or decreased absorption of the fluid is the usual cause. Hydrocephalus is treated by cerebral shunts.In paediatric patients, untreated hydrocephalus can be lethal and leads to many adverse effects including increase irritabilities, chronic headaches, learning difficulties, visual disturbances, and, in more advanced cases, severe mental retardation [1, 2]. Malfunction of the shunt with excess CSF accumulated can increase the intracranial pressure resulting in cerebral oedema and ultimately herniation. These shunts drain the CSF into the peritoneal cavity, the atrium, or the pleura, thus appropriately called ventriculoperitoneal, ventriculoatrial, and ventriculopleural shunts. CSF shunt systems fail up to 85% within 10 years from initial insertion [3, 4]. Hospitalisations for hydrocephalus have reached alarming 70,000 per year in the USA. Almost every patient with hydrocephalus (98%) will experience shunt failure in their lifetime [5]. 50% of failures occur due to tissue obstruction of the proximal (i.e. ventricular) catheter within the paediatric population [6]· The aetiology underlying this failure are still poorly understood. It was Sekhar et al. [7] who provided the description of the cell types involved in shunt catheter occlusion, and more studies have showed that astrocytes and microglia play a key role in this tissue obstruction [8].

Objective We studied and evaluated the seemingly trivial but important pure mechanical causes of shunt failure and their remedies to reduce the preventable morbidity, cost and mortality associated with shunt failure.

Methods

Our prospective observational study included 70 patients who developed pure mechanical shunt failure for the first time from 2017 to 2020 in the Department of Neurosurgery Sher-i-kashmir Institute of Medical Sciences. Patients with previous shunt surgeries which include VP shunting and shunt revision or failure and shunt infections were excluded. We have de-identified all the patients in the study.Written informed consent was obtained from all patients or their guardians in case of minors. Shunt malfunction was in the form of catheter misplacement, kinking, displacement from the ventricle or peritoneal cavity, disconnection, migration, inadvertent suturing of the catheter, air in shunt bulb. We have de-identified all patients defined shunt failure as the requirement for additional shunt surgery for any part of the shunt system because of mechanical shunt fault. Clinical criteria for shunt impairment required a history compatible with neurological decline confirmed by CT or MRI changes.The patient characteristics were studied according to age, sex, mechanism of hydrocephalus,prognosis, and clinical features. We used frontal approach in 22 patients where Kocher's point is used which is an entry point that is 11 cm superior and posterior from the nasion, 3 cm off the midline along the mid-pupillary line, and 1 to 2 cm anterior to the coronal suture; catheter was passed to a depth of 5-6 cm. We performed parieto-occipital approach in 48 patients where Keen's point is used which is approximately 2.5 to 3 cm superior and posterior to the pinna and the catheter was advanced to a depth of 4 to 5 cm.

Results

Thee age range of the study patients was between 1 week and 65 years admitted to SKIMS tertiary care hospital and included purely mechanical shunt failure during 2017 to 2020 for first time. Forty-five (64.2%) patients were male and 25 (35.7%) were female. Forty-five (64.2%) patients were infants, 7 (10%) were in toddler age group and 18 (25.7%) were adults. The most common cause was congenital abnormalities (68.5%) followed by tumour (14.2%), post-traumatic (8.5%) and post-hemmorhagic(8.5%) as shown in Table 1.

Infants mostly presented with abnormal increase in head circumference (71.1%) followed by bulging fontanelle (42.2).Delayed development, sunset sign,vomiting in gushes, irritability and reduced consciousness were the other clinical features. Toddlers and adults presented with a different set of clinical features, most common being headache(88%) followed by nausea and vomiting(40%). Diplopia, irritability and seizures were the other features as shown in Table 2.

Frontal approach was used in 22 patients where Kocher's point was used. We used Keen's point in 48 patients. Kinking at the cranial end (35%) was the most common culprit for mechanical shunt failure. Inadvertent suturing of the shunt while closing abdominal wound was responsible in (10%) of cases. Shunt disconnection at the

Table 1 Demographic profile and aetiology of our study patients

Frequency percentage			Aetiology	Frequency	Percentage
Age			1.Congenital	48	68.5
a.Infants	45	64.2	2.Tumour	10	14.2
b.toddler	7	10	3.Post traumatic	6	8.5
c.Adults	18	25.7	4.Post ICH	6	8.5
2.*Gender*					
a.Male	45	64.2			
b.Female	25	35.7			

Table 2 Clinical features of shunt malfunction in infants and adults

Infants			Toddlers And Adults		
	Frequency	Percentage		Frequency	Percentage
1.Abnormal increase in head circumference	32	71.1	1.Headache	22	88
2.Bulging fontanelle	19	42.2	2.Nausea and vomiting	10	40
3.Vomiting in gushes	4	8.8	3.Vision problems and diplopia	6	24
4.Sunset sign	4	8.8	4.Irritability	14	56
5.Irritability, listlessness	18	40	5.Seizures	5	20
6.Reduced consciousness	4	8.8			
7.Delayed development	10	22.2			

junction of the cranial and distal end was found in (8.5%) patients and air present in the shunt bulb was present in just (2.8%) of cases.

Shunt migration of the proximal end of catheter into the brain parenchyma as shown in Fig. 1 and shunt migration of the distal end of catheter through the anal canal were responsible for shunt malfunction in 5 and 1 patients, respectively.

Wrong placement of catheter at ventricular end with tip of catheter crossing septum pellucidum as shown in Fig. 2,(4), catheter just touching the frontal horn (4), catheter tip in supra-sellar cistern (2) was found in 10 (14.2%) patients.

We found lower end of shunt into the preperitoneal space with collection at the abdominal end in 4(5.7%) cases and pseudomeningocoele at the valve site in 3(4.2%) cases which was responsible for shunt failure as shown in Table 3.

Discussion

This prospective observational study evaluating 70 patients established the trivial yet indispensable and correctable causes of pure mechanical shunt failure. Most shunt malfunctions were because of kinking of the catheter at the proximal end.

Interpretation of findings

In our study,VP shunt failure occurred at the site of the proximal catheter, the valve, or the distal catheter.Our first finding was that shunt failure was predominant in male group than in female group. Most of the studies reported that VP shunt complications occurred more common in males than females [9], which was compatible with the current study as males represent 64.2% of the cases.Although the incidence of hydrocephalus is almost equal in both genders,still the shunt related problems occurring more in males needs to be elucidated further.

Our second finding was the higher risk of shunt failure in patients of younger age which was consistent with various reports that mostly depicted that the younger age group had higher shunt. malfunction rates [10, 11]. Studies by Tuli et al., Liptak and McDon- ald, and Liptak et al. depicted that shunts introduced in patients younger than 1 year had a greater failure rate [12–14]. However, multiple studies did not find age as a risk factor for shunt malfunction [15, 16] As the patients with congenital hydrocephalus undergo shunt placement earlier when we compare to patients with other aetiologies, which may reinforce the belief that younger patients have a higher failure rate. We find few mechanical causes of failure restricted to congenital hydrocephalus like migration of distal end through anal canal and migration of proximal end predominantly in infant age group.

We found an association between shunt failure and aetiology more of congenital causes developed malfunction in our study.This may be attributed to gross hydrocephalus and displacement of the of the proximal end from an overtly CSF filled ventricle into the cortical mantle, complete displacement of whole catheter into the ventricle as shown in Fig. 3 migration through the anal canal due to size of catheter in relation to the body of the infant, more chances of kinking again due to the comparative size of the catheter. Studied on particular aetiology associated with shunt malfunction was mixed [17–19]. Congenital hydrocephalus was identified as a predominant risk factor for initial shunt failure in multiple studies [20, 21].

We found kinking at the proximal end as the most common cause of shunt failure.It was mostly as a result of inadequate and less spacious tunnelling made for the reservoir.So we advocate giving ample time in making spacious tunnel for reservoir by releasing all adhesions and tissues.Albert M Issacs et al. showed that there were 4 (2%) patients with proximal failures, mostly within the first 100 days of surgery. Neuronavigation

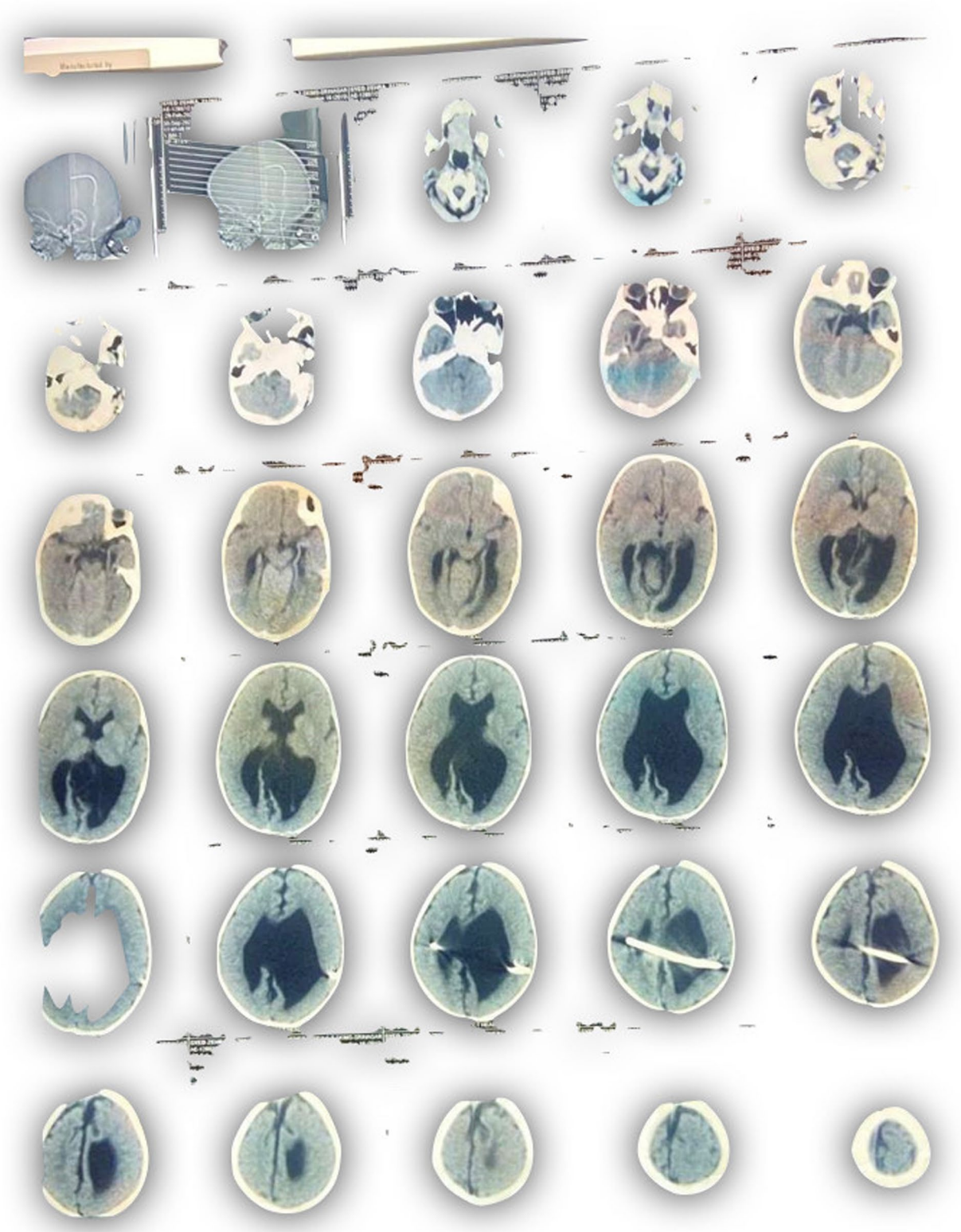

Fig. 1 Displacement of the proximal catheter tip into the brain parenchyma

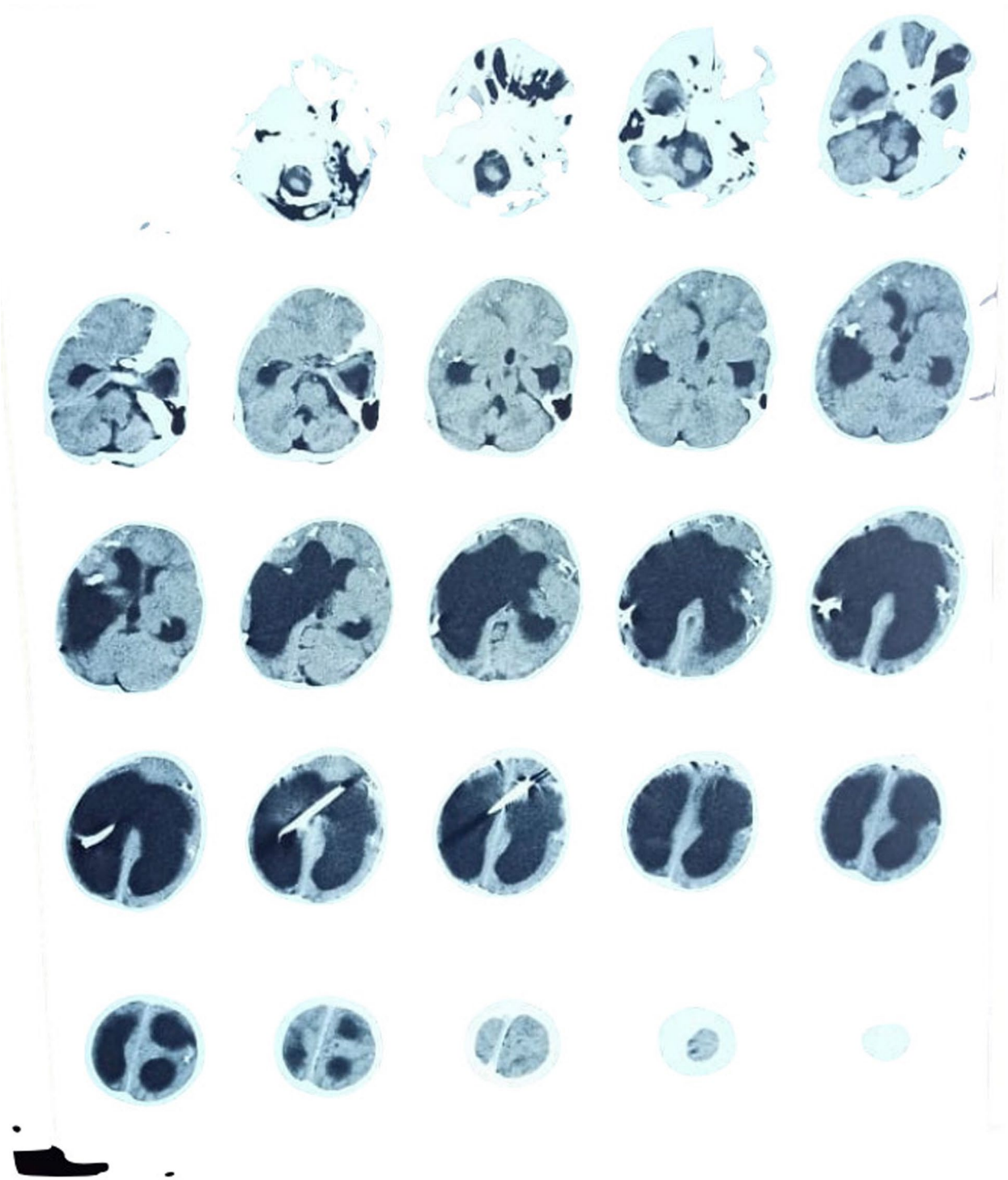

Fig. 2 Malposition of the proximal catheter crossing septum pellucidum

aided the revision of these failed shunts with complete success [22]. However, proximal end shunt failure was the predominant cause in our study.

The shunt was wrongly placed and misdirected into the ventricle in 10 cases.This may be due to lack of familiarity with the ventricular anatomy and freehand technique.It becomes extremely important to know the

Table 3 Entry point and types of mechanical failure in our study patients

Entry point			Types of mechanical failure		
	Frequency	Percentage		Frequency	Percentage
1.Kocher's point(frontal horn)	22	31.4	1.Kink	25	35.7
2.Keens point(occipital horn)	48	68.5	2.Inadvertant suturing of shunt while closing abdomen	7	10
			3. Shunt disconnection	6	8.5
			4.Air in shunt bulb	2	2.8
			5.Wrong placement at ventricular end	10	14.2
			6.Shunt migration into the brain parenchyma	5	7.1
			7.Shunt migration through the anal canal	1	1.4
			8.Pseudomeningocele around catheter valve	3	4.2
			9.Placemen of lower end into the preperitoneal space	4	5.7

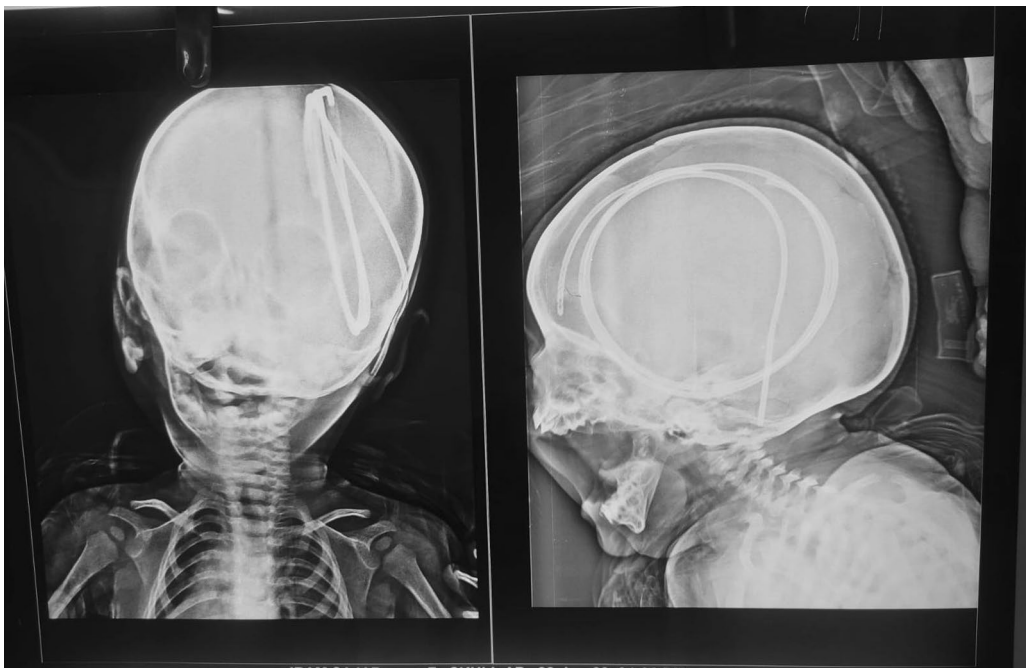

Fig. 3 Complete migration of catheter into the ventricle

landmarks precisely and gauge the ventricular depth on imaging prior to the procedure especially in freehand technique. Hamada and Abou Zeid depicted that misplacement of proximal catheter was founded in two (7.1%) patients of their shunt failure series [23].

Shunt disconnection was found at the junction of proximal and distal end.It was mainly due to lack of a proper knotting while fixing the ventricular end to peritoneal end.Proper surgical knotting should be done and knot should be placed on the exact junction to prevent obliteration of the catheter by the knot. Shunt disconnection also leads to the formation of psudomeningocoele around the valve area as shown in Fig. 4 further contributes to the failure of the shunt. Air in the shunt bulb leads to blockage and subsequent shunt failure.The remedy to prevent this was to make the reservoir air free by dipping the distal end in the kidney tray full of normal saline and pressing the bulb constantly till air bubbles disappear.15% of their shunt malfunctions were due to shuntfracture and that occipitally placed shunts had a higher migration rate than frontally placed shunts as per Aldrich and Harmann [24]

Migration of the distal end through the anal canal was the cause of failure in infants. Persistence of unobliterated

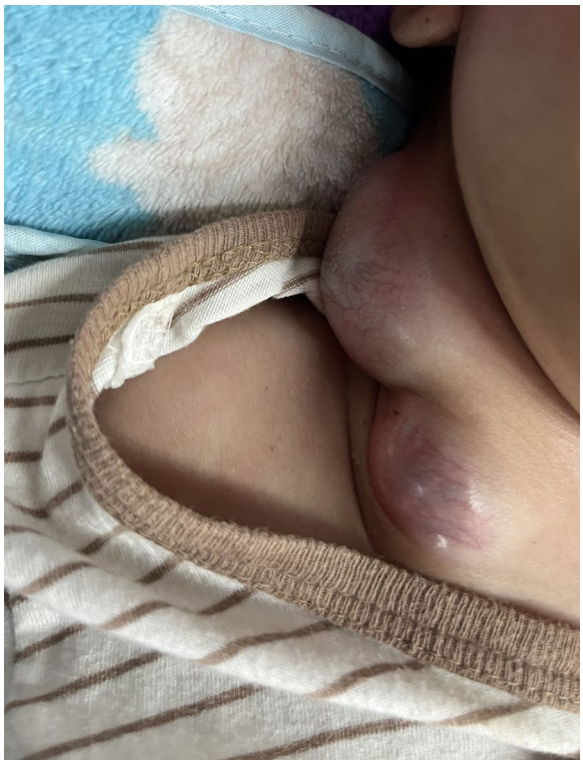

Fig. 4 Pseudomeningocele in the neck due to shunt disconnection

processus vaginalis in paediatric patients was responsible for higher likelihood of VP shunt distal catheter drifting into the scrotum [25]. Previous studies reported that age and aetiology are predominant risk factors of initial shunt failure [12, 26]. In consensus with these studies, our study showed that age and aetiology were notably associated with shunt failure where 48 (68.5%) patients with VP shunt failure were congenital in nature. Migration at the proximal end was due to lack of proper three point fixation especially in congenital gross hydrocephalus.

Inadvertent suturing of the shunt while closing abdominal layers and inadvertent placing of the shunt in the preperitoneal place leads to collection and pseudocyst formation resulting in shunt failure in cases.This misadventure can be prevented by visualising the gut loops by holding it into Babcock forceps and confirming the distal end is in the peritoneal cavity.Inadvertent suturing can be prevented by maximising the use of retractors and closing the abdomen in layered fashion with constant vigil about the position of the catheter. Abdominal complications of VP shunt are not uncommon with extra peritoneal misplacement of the catheter and sub-cutaneous or intra-abdominal cerebrospinal fluid (CSF) collections being the predominant causes [27].

Conclusions

Shunt surgery is seemingly a straightforward operation for neurosurgeons.But considering the incidence of shunt failure and its associated morbidity and mortality, it should always be done with trepidation and extreme caution.Exclusive mechanical shunt malfunction is a major concern and leads to great deal of morbidity in the shunt operations.However there are trivial remedies and technical nuances which needs to be followed during surgery to avoid these complications.Congenital hydrocephalus and younger age are the predominant risk factors for mechanical shunt malfunction.

Abbreviations

CSF Cerebrospinal fluid
VP Ventriculoperitoneal
CT Computed tomography
MRI Magnetic resonance imaging

Acknowledgements

We thank Dr Aaliya fayaz for her typographical assistance.

Author contributions

MF conception, design of the work, AK the creation of software used in the work, AAH drafted the work, SHA the acquisition, analysis and interpretation of data.

Funding

No funding was obtained for this study.

Availability of data and materials

NA.

Declarations

Ethics approval and consent to participate

The study was assessed by the Institutional Ethics Committee of SKIMS and was considered exempt from review in accordance with the observational study that was done. A written consent to participate in study was taken form the patient or guardian in case of minor.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Neurosurgery, Sher-i- Kashmir Institute of Medical Sciences, Soura, Srinagar, Jammu and Kashmir 190005, India.

Received: 3 October 2023 Accepted: 31 January 2024
Published online: 11 March 2024

References

1. Hanna RS, Essa AA, Makhlouf GA, Helmy AA. comparative study between laparoscopic and open techniques for insertion of ventriculoperitoneal shunt for treatment of congenital hydrocephalus. J Laparoendosc Adv Surg Tech A. 2019;29:109–13.
2. Erps A, Roth J, Constantini S, Lerner-Geva L, Grisaru-Soen G. Risk factors and epidemiology of pediatric ventriculoperitoneal shunt infection. Pediatr Int. 2018;60:1056–61.

3. Harris Carolyn A, Mcallister JP. What we should know about the cellular and tissue response causing catheter obstruction in the treatment of hydrocephalus. Neurosurgery. 2012;70:1589–602.
4. Hariharan P, Harris CA. Shunts and shunt malfunction. In: Limbrick D Jr, Leonard J, editors. Cerebrospinal fluid disorders. Cham: Springer; 2019.
5. Lutz B, Venkataraman P, Browd S. New and improved ways to treat hydrocephalus: pursuit of a smart shunt. Surg Neurol Int. 2013;4:38.
6. Kestle J, Drake J, Milner R, et al. Long-term follow-up data from the shunt design trial. Pediatr Neurosurg. 2000;33:230–6.
7. Sekhar LN, Moossy J, Guthkelch AN. Malfunctioning ventriculoperitoneal shunts. J Neurosurg. 1982;56:411.
8. Hanak BW, Ross EF, Harris CA, Browd SR, Shain W. Toward a better understanding of the cellular basis for cerebrospinal fluid shunt obstruction: report on the construction of a bank of explanted hydro- cephalus devices. J Neurosurg Pediatr. 2016;18:213–23.
9. Ghritlaharey RK, Budhwani KS, Shrivastava DK, et al. Ventriculoperitoneal shunt complications needing shunt revision in children: a review of 5 years of experience with 48 revisions. Afr J Paediatr Surg. 2012;9:32–9.
10. McGirt MJ, Leveque JC, Wellons JC III, et al. Cerebrospinal fluid shunt survival and etiology of failures: a seven-year institutional experience. Pediatr Neurosurg. 2002;36:248–55.
11. Kulkarni AV, Drake JM, Lamberti-Pasculli M. Cerebrospinal fluid shunt infection: a prospective study of risk factors. J Neurosurg. 2001;94:195–201.
12. Tuli S, Drake J, Lawless J, et al. Risk factors for repeated cerebrospinal shunt failures in pediatric patients with hydrocephalus. J Neurosurg. 2000;92:31–8.
13. Liptak GS, McDonald JV. Ventriculoperitoneal shunts in children: factors affecting shunt survival. Pediatr Neurosci. 1985;12:289–93.
14. Liptak GS, Masiulis BS, McDonald JV. Ventricular shunt survival in children with neural tube defects. Acta Neurochir (Wien). 1985;74:113–7.
15. Khan F, Shamim MS, Rehman A, Bari ME. Analysis of factors affecting ventriculoperitoneal shunt survival in pediatric patients. Childs Nerv Syst. 2013;29:791–802.
16. Anderson IA, Saukila LF, Robins JMW, et al. Factors associated with 30-day ventriculoperitoneal shunt failure in pediatric and adult patients. J Neurosurg. 2018;130:145–53.
17. Rossi NB, Khan NR, Jones TL, et al. Predicting shunt failure in children: should the global shunt revision rate be a quality measure? J Neurosurg Pediatr. 2016;17:249–59.
18. Iglesias S, Ros B, Martín Á, et al. Factors related to shunt survival in paediatric hydrocephalus. Could failure be avoid- ed? Neurocirugia Astur. 2017;28:159–66.
19. Beuriat PA, Puget S, Cinalli G, et al. Hydrocephalus treat- ment in children: long-term outcome in 975 consecutive patients. J Neurosurg Pediatr. 2017;20:10–8.
20. Gonzalez DO, Mahida JB, Asti L, et al. Predictors of ventriculoperitoneal shunt failure in children undergoing initial placement or revision. Pediatr Neurosurg. 2017;52:6–12.
21. Notarianni C, Vannemreddy P, Caldito G, et al. Congenital hydrocephalus and ventriculoperitoneal shunts: influence of etiology and programmable shunts on revisions. J Neurosurg Pediatr. 2009;4:547–52.
22. Isaacs AM, Ball CG, et al. Reducing the risks of proximal and distal shunt failure in adult hydrocephalus: a shunt outcomes quality improvement study. J Neurosurg. 2021;136:877–86.
23. Hamada SM, Ahmed H. Paediatric ventriculoperitoneal shunt—is free hand placement of ventricular catheter still acceptable? Egyptian J Neurosurg. 2021;30:195–8.
24. Aldrich EF, Harmann P. Disconnection as a cause of ventriculoperitoneal shunt malfunction in multicomponent shunt systems. Pediatr Neurosurg. 1990;16:309–11.
25. Kwok CK, Yue CP, Wen HL. Bilateral scrota Imigration of abdominal catheters: a rare complication of ventriculoperitoneal shunt. Surg Neurol. 1988;31:330–1.
26. Berry JG, Hall MA, Sharma V, et al. Amulti-institutional, 5-year analysis of initial and multiple ventricular shunt revisions in children. Neurosurgery. 2008;62:445–53.
27. Yung S, Chan TM. Pathophysiological changes to the peritoneal membrane during PD-related peritonitis: the role of mesothelial cells. Mediat Inflamm. 2012. https://doi.org/10.1155/2012/484167.

Publisher's Note