The Egyptian Journal of Hospital Medicine (October 2022) Vol. 89 (2), Page 7363- 7371

Management and Outcome Predictors of Pediatric Cerebrospinal Fluid Shunt Infections

Essam Mohamed Youssef[1], Magdy Elsayed Rashed[1], Belal Mohamed Elsayed[2], Magdy Omar El Sheikh[1]

[1]Department of Neurosurgery, Faculty of Medicine, Zagazig University, Egypt

[2]Department of Neurosurgery, Kafr Elshekh University Hospitals, Egypt

***Corresponding author:** Belal Mohamed Elsayed, **Mobile:** (+20) 01004390930, **E-Mail:** belalmohamed350@gmail.com

ABSTRACT

Background: Cerebrospinal fluid Shunts can cause a number of complications, the most prevalent one is infection. Infection causes significant morbidity, particularly in pediatrics more than adults, and its management is extremely challenging for healthcare systems.

Objective: This study aimed to determine the outcome predictors of pediatric shunt infections to achieve the best management plans.

Patients and methods: A prospective observational cohort study was conducted in Intensive Care Unit of Neurosurgery Department, Zagazig University Hospitals and Kafr EL-Sheikh University Hospitals. 40 pediatric patients with proved CSF shunt infection were included. All patients were subjected to clinical, laboratory and radiological assessment.

Results: Patients with CSF shunt–associated infections often presented early after shunt placement or revision with nonspecific clinical manifestations (especially fever) and abnormal CSF values. CSF sampling is preferred from the valve, where leukocyte counts and the rate of culture positivity were highest. Shunt-associated infections were caused predominantly by gram-positive skin flora. Some cases were caused by Acinetobacter species that are resistant to usually used antibiotics. Some of them improved after administration of antibiotics both systemically and intraventricularly. Outcome is significantly affected by different parameters that have been shown in our study.

Conclusion: Promising results are obtained by early removal of the shunt hardware accompanied by appropriate antibiotic therapy until CSF studies turn negative, followed by shunt replacement. Post-infectious hydrocephalus was the most common cause in our study with bad outcome. Recurrent infections occurred more commonly in children with; congenital anomalies, preterm, with intraventricular hemorrhage, with systemic and local illness, and usually had unfavorable outcomes.

Keywords: Cerebrospinal Fluid Shunt, Infections, Predictors, Outcome, Pediatrics.

INTRODUCTION

Hydrocephalus, which is frequently observed in neurosurgical practice, is caused by an accumulation of cerebrospinal fluid (CSF) inside the cerebral ventricular system. Obstructions in the flow of CSF or an inability to absorb it are the typical causes of the condition. Blood clots or erythrocytes, debris from a necrotic or inflammatory process inside the central nervous system (CNS), inflammatory edema from infection, and, infrequently, intracranial space-occupying lesions can clog the aqueduct and the other pathways [(1)].

Most cases of hydrocephalus are discovered during the first six months of life. Other cases are diagnosed later, either because of slow detection or a delayed onset. Even if the global occurrence of most of these illnesses is unknown, the assessment must nevertheless be based on data acquired locally [(2)].

Diverting the CSF from the cerebral ventricular system to another compartment where it may be absorbed either directly or indirectly into the circulation is the preferred therapy for symptomatic hydrocephalus, and this can be achieved by the shunting system. The most commonly used is the ventriculoperitoneal shunt [(3)].

The most frequent complication of shunts is infection, which has significant morbidity, particularly in the growth and development of the afflicted children, as well as significant financial expenses for healthcare systems. The prevalence of shunt infection ranges from 10% to 22% [(4)], and typically affect pediatrics more frequently than adults. Skin germs that colonize the shunt following implantation is the main cause of infections. Staphylococcus epidermidis, which accounts for 60% of all infections, is followed by S. aureus (30%). Shunt infections seldomly occur more than six months following surgery, usually during the first month after shunt insertion [(5)].

Fever, irritability, anorexia, or pain along the shunt tract are symptoms of a shunt infection. A patient's clinical presentation, a CSF sample taken after tapping the reservoir, or a blood sample can all be used to identify an infection. Shunt infection symptoms must also be distinguished clinically and by examinations from other causes of systemic illness in children as well as other neurological infections (brain abscess, subdural empyema, etc.). In order to effectively treat shunt infections, the shunt should often be temporarily removed, a ventricular drain is used, and intravenous antibiotics are given [(6)].

The aim of this study was to determine the outcome predictors of pediatric shunt infections in order to achieve the best management plans.

PATIENT AND METHOD

A prospective, observational cohort study done in Neurosurgery Department, Zagazig University

Received: 15/07/2022
Accepted: 18/09/2022

Hospitals and Kafr EL-Sheikh University Hospitals. 40 pediatric patients with proved cerebrospinal fluid shunt infection were included, during the period from October 2021 to April 2022.

Inclusion criteria:

Patients with proved CSF all types of shunt infection ages < 18 years.

Exclusion criteria:

Patients having shunt malfunction other than shunt infection or aged above 18 years.

All patients were subjected to history taking, fever recording (grade, timing and duration), time of shunt insertion, revision and corresponding age of the patient, associated systemic illness especially causing immunocompromization and proper general and neurological examination.

Laboratory investigations included CBC, ESR, CRP, LFTs, KFTs, Blood culture and CSF analysis.

Radiological investigations including CT brain and MRI when needed. Chest x-ray, pelvi-abdominal ultrasound and superficial ultrasound of localized collections along shunt track.

Follow-up with every case to detect general situation & outcomes. All data were noted, analyzed and compared.

Ethical consent:

Zagazig University Faculty of Medicine's Ethics Committee approved this study [IRB approval # (8022)], which was carried out in accordance with the guidelines outlined in the Declaration of Helsinki. Every patient's parent gave approval consent for participation in this study.

Statistical analysis

In order to analyze the data acquired, Statistical Package of Social Sciences version 20 was used to execute it on a computer (SPSS). Categorical variables were expressed as number (percentage). Continuous variables were expressed as mean ± SD & median (range). Chi-square test & Mann Whitney U test were used. p-value ≤ 0.05 is significant.

RESULTS

The most common cause among the studied patients was post-infection (37.5%) followed by congenital causes (20%), then post hemorrhagic and post traumatic causes (15%) and secondary to mass lesion causes with the least incidence (12.5%). There was statistically non-significant relation between initial cause of hydrocephalus and outcome of studied patients (66.7% of those with IVH, 33.3% with post-infectious causes, 20% of those with hydrocephalus secondary to mass lesion, 66.7% of post-traumatic causes, and 37.5% of congenital causes had favorable outcome) (Table 1).

Table (1): Relationship between initial cause of hydrocephalus and outcome of patients that underwent shunt revision

Cause	All patients (n=40)			Outcome				Test	p-value (Sig.)
				Favorable (n=17, 42.5%)		Unfavorable (n=23, 57.5%)			
	No.	%		No.	%	No.	%		
Intraventricular hemorrhage	6	15%		4	66.7%	2	33.3%	4.501 [a]	0.342
Post-infectious	15	37.5%		5	33.3%	10	66.7%		(NS)
Secondary to mass	5	12.5%		1	20.0%	4	80.0%		
Post-traumatic	6	15%		4	66.7%	2	33.3%		
Congenital	8	20%		3	37.5%	5	62.5%		

Categorical variables were expressed as number (percentage).

There was a significant association between risk factors and outcome where 81.2% of patients with at least one risk factor had unfavorable outcome versus 41.7% among patients without risk factor (p-value=0.013). There was a significant association between maternal nutrition and outcome where (100%) of patients with poor maternal nutrition had unfavorable outcome versus 50% among patients without poor maternal nutrition (p-value=0.030). There was a significant association between incubation and outcome where 80% of incubated patients had unfavorable outcome versus 44% among non-incubated (p-value=0.046) (Table 2).

Table (2): Relationship between prenatal, natal/postnatal risk factors and outcome of patients that underwent shunt revision

Prenatal, natal/postnatal risk factors	All patients (n=40)		Outcome				Test[a]	p-value (Sig.)
			Favorable (n=17, 42.5%)		Unfavorable (n=23, 57.5%)			
	No.	%	No.	%	No.	%		
Risk factor								
Absent	24	60%	14	58.3%	10	41.7%	6.155	0.013
Present	16	40%	3	18.8%	13	81.2%		(S)
Preterm								
Absent	31	77.5%	15	48.4%	16	51.6%	1.954	0.256
Present	9	22.5%	2	22.2%	7	77.8%		(NS)
Postnatal fever								
Absent	38	95%	17	44.7%	21	55.3%	1.556	0.499
Present	2	5%	0	0%	2	100%		(NS)
Convulsions								
Absent	38	95%	17	44.7%	21	55.3%	1.556	0.499
Present	2	5%	0	0%	2	100%		(NS)
Poor suckling								
Absent	34	85%	14	41.2%	20	58.8%	0.162	1.000
Present	6	15%	3	50%	3	50%		(NS)
Intraventricular hemorrhage								
Absent	33	82.5%	16	48.5%	17	51.5%	2.764	0.205
Present	7	17.5%	1	14.3%	6	85.7%		(NS)
Maternal folic acid deficiency								
Absent	35	87.5%	17	48.6%	18	51.4%	4.224	0.061
Present	5	12.5%	0	0%	5	100%		(NS)
Delivery with bulging font.								
Absent	16	40%	7	43.8%	9	56.2%	0.017	0.896
Present	24	60%	10	41.7%	14	58.3%		(NS)
Hypoxic at birth								
Absent	37	92.5%	16	43.2%	21	56.8%	0.112	1.000
Present	3	7.5%	1	33.3%	2	66.7%		(NS)
Poor maternal nutrition								
Absent	34	85%	17	50%	17	50%	5.217	0.030
Present	6	15%	0	0%	6	100%		(S)
ARDS								
Absent	39	97.5%	17	43.6%	22	56.4%	0.758	1.000
Present	1	2.5%	0	0%	1	100%		(NS)
Maternal preeclampsia								
Absent	39	97.5%	16	41%	23	59%	1.388	0.425
Present	1	2.5%	1	100%	0	0%		(NS)
Incubation								
Absent	25	62.5%	14	56%	11	44%	4.972	0.046
Present	15	37.5%	3	20%	12	80%		(S)

Categorical variables were expressed as number (percentage); Continuous variables were expressed as mean ± SD & median (range); a: Chi-square test; b: Mann Whitney U test; p-value< 0.05 is significant; Sig.: Significance

There was a significant association between associated congenital anomalies and outcome where 78.9% of patients with at least one associated congenital anomaly had unfavorable outcome versus 38.1% among patients without associated congenital anomalies. (p-value=0.009) (Table 3).

Table (3): Relationship between associated congenital anomalies and outcome of patients that underwent shunt revision

Associated congenital anomalies	All patients (n=40)		Outcome				Test[a]	p-value (Sig.)
			Favorable (n=17, 42.5%)		Unfavorable (n=23, 57.5%)			
	No.	%	No.	%	No.	%		
Associated congenital anomalies								
Absent	21	52.5%	13	61.9%	8	38.1 %	6.812	0.009
Present	19	47.5%	4	21.1%	15	78.9 %		(S)
MMC (myelomeningocele)								
Absent	34	85%	15	44.1%	19	55.9 %	0.243	1.000
Present	6	15%	2	33.3%	4	66.7 %		(NS)
Spina bifida								
Absent	35	87.5%	17	48.6%	18	51.4 %	4.224	0.061
Present	5	12.5%	0	0%	5	100%		(S)
MC (meningocele)								
Absent	37	92.5%	16	43.2%	21	56.8 %	0.112	1.000
Present	3	7.5%	1	33.3%	2	66.7 %		(NS)

Categorical variables were expressed as number (percentage); Continuous variables were expressed as mean ± SD & median (range); a: Chi-square test; b: Mann Whitney U test; p-value< 0.05 is significant; Sig.: Significance

There was a significant association between previous shunt malfunction or infection and outcome where 80% of patients with previous shunt malfunction or infection history had unfavorable outcome versus 20% among patients without previous shunt malfunction or infection history (p-value<0.001). Patients with unfavorable outcome had a significantly higher mean number of revisions than patients with favorable outcome (Mean: 1.39 versus 0.21 respectively, p-value=0.004). There was a significant association between number of revisions and outcome where 100% of patients with three revisions had unfavorable outcome versus 20% among patients without previous revisions (p-value<0.001) (Table 4).

Table (4): Relationship between previous shunt malfunction or infection/its characters and outcome of patients that underwent shunt revision

Previous shunt malfunction or infection/its characters	All patients (n=40)		Outcome				Test	p-value (Sig.)
			Favorable (n=17, 42.5%)		Unfavorable (n=23, 57.5%)			
	No.	%	No.	%	No.	%		
Previous shunt malfunction or infection								
Absent	15	37.5%	12	80%	3	20%	13.811[a]	<0.001
Present	25	62.5%	5	20%	20	80%		(HS)
Number of revisions								
Mean ± SD	1.02±0.21		0.52±0.12		1.39±0.22		-2.891[b]	0.004
Median (Range)	1 (0-3)		0 (0-2)		1 (0-3)			(S)
No	15	37.5%	12	80%	3	20%	18.218[a]	<0.001
One	13	32.5%	1	7.7%	12	92.3%		(HS)
Two	8	20%	4	50%	4	50%		
Three	4	10%	0	0%	4	100%		
Cranial end								
NAD	14	35%	6	42.9%	8	57.1%	0.001[a]	0.973
Inflammed	26	65%	11	42.3%	15	57.7%		(NS)
Peritoneal end								
NAD	13	32.5%	5	38.5%	8	61.5%	0.129[a]	0.720
Inflammed	27	67.5%	12	44.4%	15	55.6%		(NS)
Valve								
Not exposed	14	35%	8	57.1%	6	42.9%	1.890[a]	0.169
Exposed	26	65%	9	34.6%	17	65.4%		(NS)
Pumping								
Normal	5	12.5%	3	60%	2	40%	0.716[a]	0.634
Delayed	35	87.5%	14	40%	21	60%		(NS)

Categorical variables were expressed as number (percentage); Continuous variables were expressed as mean ± SD & median (range); a: Chi-square test; b: Mann Whitney U test; p-value< 0.05 is significant; Sig.: Significance

There was a significant association between duration of operation and outcome where 76.2% of patients with long duration of operation had unfavorable outcome versus 36.8% among patients with short duration of operation (p-value=0.012).

Patients with unfavorable outcome had a significantly higher mean number of attendants than patients with favorable outcome (Mean: 3.78 versus 3.05 respectively, p-value=0.007). There was a significant association between number of attendants and outcome where 80% of patients with five attendants had unfavorable outcome versus (0%) among patients with few attendants (two attendants) who had favorable outcome (p-value=0.031). There was a significant association between number of attendants and outcome where 77.8% of patients with many attendants had unfavorable outcome versus 40.9% among patients with few attendants (p-value=0.019). There was a significant association between laboratory finding before revision and outcome where (100%) of patients without relieved infection had unfavorable outcome versus (48.4%) among patients with relieved infection (p-value=0.014). Patients with unfavorable outcome had a significantly higher mean WBCs count in CSF analysis than patients with favorable outcome (Mean: 764.11 versus 1039.13 cell/mm^3 respectively, p-value=0.002).

There was a significant association between organism revealed in culture from CSF and outcome where 100% of patients with mixed organism and Acinetobacter infections had unfavorable outcome, versus 27.3% among patients with staph species infection (p-value=0.027). There was a significant association between antibiotic sensitivity test and outcome where 100% of patient with bacteria sensitive to cefepime had unfavorable outcome versus 27.3% among patients with bacteria sensitive to vancomycin (p-value=0.049) (Table 5).

Table (5): Relationship between operation data, laboratory studies and outcome of patients underwent shunt revision

Operation data	All patients (n=40)		Outcome				Test	p-value (Sig.)
			Favorable (n=17, 42.5%)		Unfavorable (n=23, 57.5%)			
	No.	%	No.	%	No.	%		
Duration of operation (min)								
Mean ± SD	94.62±18.02		85.58±16.75		101.30±16.18		-2.783[b]	0.005
Median (Range)	95 (65-130)		80 (65-120)		100 (70-130)			(S)
Short	19	47.5%	12	63.2%	7	36.8%	6.320[a]	0.012
Long	21	52.5%	5	23.8%	16	76.2%		(S)
Number of attendants								
Mean ± SD	3.47±0.84		3.05±0.75		3.78±0.73		-2.695[b]	0.007
Median (Range)	3 (2-5)		3 (2-5)		4 (3-5)			(S)
Two attendants	4	10%	4	100%	0	0%	8.869[a]	0.031
Three attendants	18	45%	9	50%	9	50%		(S)
Four attendants	13	32.5%	3	23.1%	10	76.9%		
Five attendants	5	12.5%	1	20%	4	80%		
Few attendants	22	55%	13	59.1%	9	40.9%	5.507[a]	0.019
Many attendants	18	45%	4	22.2%	14	77.8%		(S)
Lab finding & CSF sampling								
Negative	0	0%	0	0%	0	0%	0.000[a]	1.000
Indicative for infection	40	100%	17	42.5%	23	57.5%		(NS)
Lab finding before revision								
Not relieved infection	7	17.5%	0	0%	7	100%	6.271[a]	0.014
Relieved infection	33	82.5%	17	51.5%	16	48.5%		(S)
WBCs in CSF (cell/mm^3)								
Mean ± SD	922.25±227.62		764.11±189.14		1039.13±252.32		-3.167	0.002 (S)
Protein in CSF (mg/dl)								
Mean ± SD	174.75±41.24		161.17±38.64		184.78±42.31		-1.126[b]	0.260 (NS)
Organism								
Staph species	11	27.5%	8	72.7%	3	27.3%	12.658[a]	0.027
Pseudomonas	8	20%	5	62.5%	3	37.5%		(S)
Klebsiella	8	20%	3	37.5%	5	62.5%		
E. coli	4	10%	1	25%	3	75%		
Acinatobacter species	5	12.5%	0	0%	5	100%		
Mixed organisms	4	10%	0	0%	4	100%		
Antibiotics								
Vancomycin	11	27.5%	8	72.7%	3	27.3%	12.658[a]	0.049
Ceftazidime	8	20%	5	62.5%	3	37.5%		(S)
Meropenem	8	20%	3	37.5%	5	62.5%		
Ceftriaxone	4	10%	1	25%	3	75%		
Penicillin	4	10%	0	0%	4	100%		
Sulbactam	2	5%	0	0%	2	100%		
Cefepime	3	7.5%	0	0%	3	100%		
Surgical correction ways								
Shunt removal	17	42.5%	8	47.05%	9	52.95%	6.271a	(NS)
Externalization of the shunt	14	35%	4	28.5%	10	71.5%		(NS)
Extr ventricular drain (EVD)	9	22.5%	5	55.5%	4	44.5%		(NS)

Categorical variables were expressed as number (percentage); Continuous variables were expressed as mean ± SD & median (range); a: Chi-square test; b: Mann Whitney U test; p-value< 0.05 is significant; Sig.: Significance

There was a statistically significant relation between ways of antibiotic administration and outcome of studied patients. 20.7% of those with systemic antibiotic, all those received intraventricular and combined routes had favorable outcome (Table 6).

Table (6): Relationship between ways of antibiotic administration and outcome of patients that underwent shunt revision

Cause	All patients (n=40)		Outcome				Test	p-value (Sig.)
			Favorable (n=17, 42.5%)		Unfavorable (n=23, 57.5%)			
	No.	%	No.	%	No.	%		
Systemic antibiotics	29	72.5%	6	20.7 %	23	79.3%	20.53[a]	0.001
Intraventricular antibiotics	5	12.5%	5	100%	0	0%		(S)
Both	6	15%	6	100%	0	0%		

Categorical variables were expressed as number (percentage); Continuous variables were expressed as mean ± SD & median (range); a: Chi-square test; b: Mann Whitney U test; p-value< 0.05 is significant; Sig.: Significance

There is a statistically significant relation between CSF clearance interval and outcome of studied patients, the longer the clearance interval, the worse the outcome (mean clearance interval in those with favorable outcome was 9 days versus 23.7 days in those with unfavorable outcome) (Table 7).

Table (7): Relationship between operation data, laboratory studies, CSF clearance interval and outcome of patients that underwent shunt revision

Operation data	All patients (n=40)		Outcome				Test	p-value (Sig.)
			Favorable (n=17, 42.5%)		Unfavorable (n=23, 57.5%)			
	No.	%	No.	%	No.	%		
CSF clearance interval (day)								
Mean ± SD	17.45±4.29		9.0±1.73		23.7±3.05		-19.27[b]	0.001 (S)

Categorical variables were expressed as number (percentage); Continuous variables were expressed as mean ± SD & median (range); a: Chi-square test; b: Mann Whitney U test; p-value< 0.05 is significant; Sig.: Significance

Our study was performed on 40 patients under so many different variables and so that the outcome is variable ranging between favorable and unfavorable outcome, and this was the main aim of the study to find the best predictive criteria affecting the outcome of pediatric shunt infections. Twenty-three patients (57.5%) had unfavorable outcome and seventeen patients had favorable outcome (42.5%) (Figure 1).

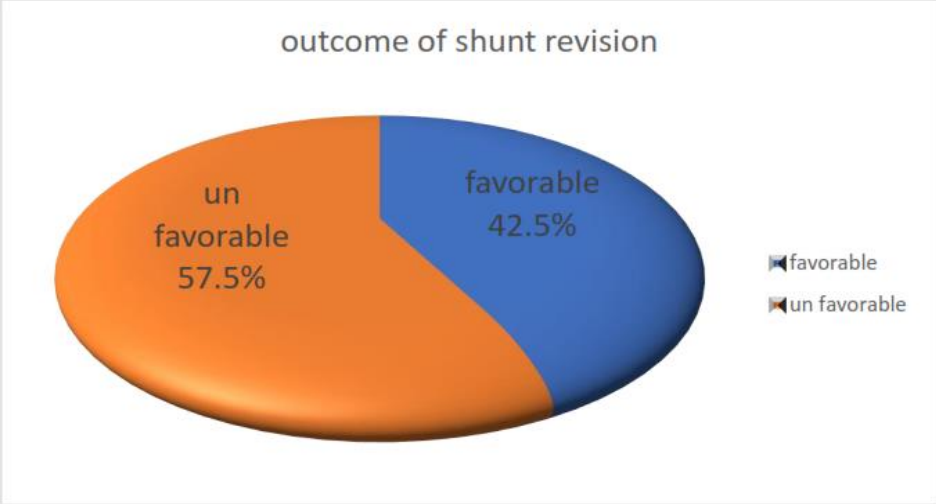

Figure (1): Outcome of shunt revision

DISCUSSION

Regarding Prenatal, natal and postnatal risk factors in our study, there was a significant association between risk factors and outcome where 81.2% of patients with at least one risk factor had unfavorable outcome versus 41.7% among patients without risk factor (p-value=0.013). Also there was a significant association between maternal nutrition and outcome, where (100%) of patients with poor maternal nutrition had unfavorable outcome versus (50%) among patients without poor maternal nutrition (p-value=0.030). There was a significant association between incubation and outcome, where (80%) of incubated patients had unfavorable outcome versus (44%) among non-incubated. According to **Salvador *et al.* [7],** it has been believed that low socioeconomic states and poor maternal nutrition have been risk factors for all non-genetic defects including hydrocephalus as well as neonatal infections. Multivitamin supplements during pregnancy have been shown to reduce the risk of hydrocephalus and its infection. In a study conducted by **Spader *et al.* [8],** incubated premature infants with intraventricular hemorrhage often had hydrocephalus which requires shunting with high rate of infection and bad outcome (Both are agreeing with our study).

Regarding Associated congenital anomalies: In our study**,** there was a significant association between associated congenital anomalies and outcome, where 78.9% of patients with at least one associated congenital anomaly had unfavorable outcome versus 38.1% among patients without associated congenital anomalies (p-value=0.009). The most significant anomaly affecting outcome was spina bifida, there were five patients (12.5%) that had spina bifida, all of them had unfavorable outcome. According to a study conducted by **Yakut *et al.* [9],** the study included 290 patients with hydrocephalus, all had ventriculoperitoneal shunt for hydrocephalus, 190 of them had congenital malformations with bad outcome and high shunt infection rates**.** According to **Norkett *et al.* [10],** hydrocephalus has commonly associated with open spina bifida, which requires shunting. In their study, the outcome in patients with open spina bifida was not good, as 98% of patients that needed shunting had at least one shunt revision.

In this study, regarding Previous shunt malfunction or infection, there was a significant association between previous shunt malfunction or infection and outcome, where 80% of patients with previous shunt malfunction or infection history had unfavorable outcome versus 20% among patients without previous shunt malfunction or infection history (p-value<0.001). Patients with unfavorable outcome had a significantly higher mean number of revisions than patients with favorable outcome (Mean: 1.39 versus 0. 21 respectively, p-value=0.004). There was a significant association between number of revisions and outcome, where 100% of patients with three revisions had unfavorable outcome versus 20% among patients without previous revisions (p-value<0.001). **According to Mansoor *et al.* [11],** 81 patients underwent 206 surgeries in the study period. 47 patients (58%) required a minimum of one revision during follow-up. In 14 patients (29.8%), the first revision was due to hardware misplacement. Proximal occlusion of shunt system was the most common cause of revision (30.4%) followed by misplacement (18.5%) and infection (9.6%). Children were prone to high revision and complication rates. In their study, misplacement of hardware and proximal occlusion were the most common causes for revision followed by infection, which agree with our study.

In our study, **regarding the ways of administration of antibiotics to control infection,** 29 patients (72.5%) received systemic antibiotics, 5 patients (12.5%) received intraventricular antibiotics and 6 patients (15%) received antibiotics by both ways, there is a statistically significant relation between ways of antibiotic administration and outcome of studied patients (20.7% of those with systemic antibiotic, all those received Intraventricular and combined routes had favorable outcome). In our study, antibiotics were used according to culture and sensitivity tests as following: 1-vancomycin was given to 11 patients (27.5%) 8 (72.7%) of them had favorable outcome and the other three (27.3%) had unfavorable outcome. 2-ceftazidime was given to 8 patients (20%), 5 (62.5%) of them had favorable outcome and 3 (37.5%) had unfavorable outcome. 3- meropenem was given to 8 (20%) patients, 3 (37.5%) of them had favorable outcome and 5 (62.5%) had unfavorable outcome . 4-ceftriaxone was given to 4 patients (10%), one of them (25%) had favorable outcome and 3 (75%) had unfavorable outcome. 5-penicillin was given to 4 patients (10%) no one had favorable outcome. 6- sulbactam was given to 2 patients (5%) and no one had favorable outcome. 7- cefepime was given to 3 patients (7.5%) and no one had favorable outcome, in the last three scenarios we have tried both systemic and intraventricular pathways to improve the outcome. **According to Wang *et al.* [12],** intraventricular plus systemic antibiotics administration in case of resistant infections have resulted in very good outcomes.

Rregarding ways of management of shunt infections, we have followed the recent guidelines in our management both surgically and medically. Any patient presented with manifestations of shunt infection, a CSF sample was obtained from the reservoir for culture, sensitivity and cytochemical analysis, and we gave the patients in our study empirical antibiotics in an attempt to control the infection till we had got the culture and sensitivity results (mostly we used vancomycin and a gram negative covering agent such as cefepime), followed by surgical removal of the shunt system. Surgical options included: Shunt removal, external ventricular drainage and shunt externalization. Some cases had external ventricular drainage (EVD) (in 9 cases, 5 with favorable and 4 with unfavorable outcome) and others were subjected to shunt externalization that was followed by shunt replacement after infection had

been controlled with a clear CSF (in 14 cases, 4 with favorable and 10 with unfavorable outcome), and other cases were subjected to shunt system removal till infection was controlled then followed by a new shunt system placement (in 17 cases, 8 with favorable and 9 with unfavorable outcome). During the period of EVD or shunt externalization we gave medical treatment (Antibiotics) according to culture and sensitivity results.

In our study we gave vancomycin in 11 cases 8 of them had favorable outcome, ceftazidime in 8 cases 5 of them had favorable outcome, meropenem in 8 cases 3 of them had favorable outcome, ceftriaxone in 4 case one of them had favorable outcome, penicillin in 4 cases all of them had unfavorable outcome, sulbactam in 2 cases all of them had unfavorable outcome, cefepime in 3 cases all of them had unfavorable outcome. So that in resistant cases of infection or when it was hard to remove the shunt system, we used both intravenous and intraventricular antibiotics to improve the outcome (mostly we used vancomycin and gentamycin in our resistant cases, and in cases resistant to vancomycin we had tried linezolid 10 mg/kg/8 hours and there was a better outcome with it). Once the CSF follow up samples were sterile, we had replaced the shunts again in case of externalization or re-shunting in case of EVD. **According to Chakravarthy *et al.* [13],** current recommendations for the empirical treatment of central nervous system (CNS) infection in the presence of a shunt recommend using IV vancomycin in combination with an agent that has adequate gram-negative coverage, such as cefepime, ceftazidime, cefotaxime, or meropenem. The ability of medication to penetrate the CSF as well as the activity of the antibiotic against the bacterial biofilm are also important to consider for antibiotic choice, which agrees with our study. According to **van de Beek *et al.* [14],** in the case of complicated or treatment-resistant shunt infections, clinicians should consider intrathecal or intraventricular administration of antibiotics for increased efficacy due to their ability to achieve higher bactericidal concentrations within the CNS. Vancomycin and gentamycin are commonly used in this situation that agrees with our study.

CONCLUSION

The infection rate in patients with ventriculoperitoneal shunt was ranging between 3-20% (typically ≈ 7%). Pre-operative CSF clearance results are very important to exclude infection to replace a new shunt to manage the condition, the outcome predictors and management of pediatric shunt infections are challenging, since there are so many variable parameters to be measured including: personal, demographic data, risk factors, initial cause of hydrocephalus, systemic, local illness, congenital anomalies and ways of management. In our study we determined some of important parameters that greatly affected the outcome according to each case including 1- the longer the CSF clearance interval, the worse the outcome, 2-The more the number of the attendants the more the rate of shunt infection and the worse the outcome, 3- Acinetobacter spices infection is very resistant, slightly responding to unusually used antibiotics as sulbactam and cefepime and had bad outcome, 4- Antibiotics should be given according to CSF culture and sensitivity results to achieve the best results in clearing infections and to avoid the development of resistant strains,5- Both intraventricular and systemic antibiotics are associated with the best outcome results.

Financial support and sponsorship: Nil.
Conflict of interest: Nil.

REFERENCES

1. **Akins P, Guppy K (2019):** Are hygromas and hydrocephalus after decompressive craniectomy caused by impaired brain pulsatility, cerebrospinal fluid hydrodynamics, and glymphatic drainage? Literature overview and illustrative cases. World Neurosurg., 130: 941–952.
2. **Tullberg M, Persson J, Petersen J *et al.* (2018):** Shunt surgery in idiopathic normal pressure hydrocephalus is cost-effective—a cost utility analysis. Acta neurochirurgica, 160 (3): 509-518.
3. **Luisetto M, Ahmadabadi B, Rafa A *et al.* (2019):** The turing machine theory for some spinal cord and brain condition, A toxicological - antidotic depurative approach. J Neurosci Neurol Disord., 3: 102-134.
4. **Dorresteijn K, Brouwer M, Jellema K *et al.* (2020):** Bacterial external ventricular catheter-associated infection. Expert Review of Anti-infective Therapy, 18: 219 – 229.
5. **Bayston R (2018):** Cerebrospinal fluid shunt infection: microbiological basis. In Ozek M, Sainte-Rose C, Cinalli G (Eds.), Pediatric hydrocephalus. Cham: Springer Publishing Company, Pp: 1-19. https://doi.org/10.1007/978-3-319-31889-9_76-1
6. **Sangeetha M (2019):** Ventriculoperitoneal shunts infections in paediatric patients. Coimbatore Medical College, Coimbatore, Pp: 1-139. http://repository-tnmgrmu.ac.in/11136/1/200400719sangeetha.pdf
7. **Salvador S, Henriques J, Munguambe M *et al.* (2014):** Hydrocephalus in children less than 1 year of age in northern Mozambique. Surg Neurol Int., 5: 175. doi: 10.4103/2152-7806.146489
8. **Spader H, Hertzler D, Kestle J *et al.* (2015):** Risk factors for infection and the effect of an institutional shunt protocol on the incidence of ventricular access device infections in preterm infants. J Neurosurg Pediatr., 15 (2): 156-60.
9. **Yakut N, Soysal A, Kepenekli Kadayifci E *et al.* (2018):** Ventriculoperitoneal shunt infections and re-infections in children: a multicentre retrospective study. Br J Neurosurg., 32 (2): 196-200.
10. **Norkett W, McLone D, Bowman R (2016):** Current management strategies of hydrocephalus in the child with open spina bifida. Topics in Spinal Cord Injury Rehabilitation, 22 (4): 241-246.
11. **Mansoor N, Solheim O, Fredriksli O (2021):** Shunt complications and revisions in children: A retrospective single institution study. Brain Behav., 11 (11): e2390. doi: 10.1002/brb3.2390
12. **Wang H, Zhou Q, Huang K *et al.* (2022):** Intraventricular plus systemic antibiotic therapy for treating polymyxin-resistant klebsiella pneumoniae ventriculitis: A case report. Open Forum Infectious Diseases, 9 (4): ofac084. doi: 10.1093/ofid/ofac084
13. **Chakravarthy V, Ramos A, Garton A *et al.* (2021):** Book Review: Schmidek and Sweet: Operative Neurosurgical Techniques 2-Volume Set. Elsevier, Amsterdam, Pp: 234-248. https://en.x-mol.com/paper/article/1485698823023247360
14. **van de Beek D, Drake J, Tunkel A (2010):** Nosocomial bacterial meningitis. New England Journal of Medicine, 362 (2): 146-154.