Ventriculo-Peritoneal Shunt Complications at Emergency Teaching Hospital in Duhok City

ABSTRACT

Background. Ventriculoperitoneal (VP) shunt surgery is the predominant mode of therapy for patients with hydrocephalus. However, it has potential complications that may require multiple surgical procedures during a patient's lifetime. The aim of the article was to review the experience in a 2-year teaching hospital and toevaluate the risk factors for PV shunt failure after initial shunt surgery and after subsequentreviews.**Methods.** The study was carried out at The Emergency Teaching Hospital in Duhok City in Iraq. All complications of VP shunted patients admitted to the hospital from January 2013 to January 2015, were included in the study. Forty six patients (out of 170 VP shunt operations), with all shunt related complications, qualified for this study. Identification of patients with complications of VP shunt is done by obtaining proper history, examination, and identification of ventricular enlargement with periventricular edema on imaging (brain computed tomography (CT) or magnetic resonance study (MRI); also, identification of any evidence of device migration by direct vision, chest and abdominal X-ray and evidence of infection on CSF analysis.**Results.** Theincidence of the complications was (27.1%). There were 24 (52.2%) males and 22 (47.8%) females. Males were affected more than females with a ratio 1.1:1. Their age ranged from 2 months to 67 years, with mean age 8.6 years. The most common cause for the initial VP shunt implantation was congenital hydrocephalus and was noticed in 34 (73.9%) patients. Mean duration to develop VP shunt complication was 26.6 months. The most common presenting symptom in pediatric patients was decreased oral intake in 37 (80.4%) patients; however, in adult patients, it was headache, 4 (80%) patients. The most common complication was obstruction, 25 (54.3%) patients, followed by infection in 9 (19.6%) patients. The most common treatment option given to the patients who suffered from VP shunt complications was whole system change for a new one, in 15 (32.6%) patients. **Conclusions.** The findings of the study indicate that age of the patient at time of shunt placement, etiology of hydrocephalus, and previous treatments before shunt surgery were independently significantly associated with the shunt survival. Prospective controlled studies are required to address the observed associations between the risk factors and incidence of shunt revisions in these patients.

KEY WORDS.Cerebrospinal fluid, communicating hydrocephalus, obstructive hydrocephalus, shunt complication, shunt failure, shunt revision.

Introduction

Hydrocephalus represents a disparity between production and absorption of cerebrospinal fluid (CSF), resulting in raised intracranial pressure with or without ventricular dilatation.Hydrocephalus is one of the more common neurologic sequelae following insult to the central nervous system. It can be congenital or acquired.The incidence of congenital hydrocephalus has been estimated to be 0.48 and 0.81 cases per 1000 live births(1).Shunt surgery is one of the most unforgiving types of surgery undertaken by the neurosurgeon. The vast majority of shunt complications are due to either blockage or infection. The incidence of these complications is largely related to factors that the surgeons can influence (2).Appropriate prophylaxis against infection is critical. Virtually all shunt infections occur as a result of microbial inoculation of the shunt at the time of insertion, preparation of the scalp and the skin is the first step of infection prophylaxis (2).Administration of a weight-appropriate dose of preoperative antibiotic has also been demonstrated to reduce infection rates.Many surgeons prefer to continue antibiotics postoperatively for one dose or 24 hours (2).Generally, these valves functioned well, but over time it became evident that debilitating over drainage headaches still developed in up to 10% to 12% of patients with fixed-pressure valves. This led to the development of flow-regulated valves, which regulated the amount of flow through the system when they were functioning within the normal physiologic range (3).Shunt infection occurs in about 5-10% of the procedures (4).Forty percent of shunt infections are caused by *S. epidermidis*, while 20% by *S. aureus*. The remainders are a variety of organisms including *Streptococci*, aerobic gram negative rods, *enterococci*, *E. coli* and yeasts (4).In most shunt infections the infection is spread to the surgical wound either directly from the adjacent skin or by gloves and instruments contaminated by the patient's flora.Researchers showed that the density of pre-operative skin bacteria was significantly higher in those patients who developed shunt infection(5).In late infections, if the organism is a gram negative an underlying condition (i.e. bowl erosions, skin breakdown, etc.) should be sought (5).Implanted shunt is almost immediately coated with a glycoproteinaceousfilm, which is derived from serum and extracellular matrix protein. This provides potential receptor sites for bacterial or tissue adhesion.If tissue cells are first to adhere to and integrate with the shunt surface, then the surface resists bacterial colonization(6).Bacterial adhesion and multiplication produce a biofilmon the surface of the shunt which will eventually produce a clinical shunt infection. This biofilm reduces the penetration of antibiotics and prevent elimination of bacteria with treatment with antibiotics alone.*S. aureus* lacks the ability to adhere to shunt surfaces and usually produce a wound infection. *S. epidermidis* produces an extracellular slime and therefore bind well to a shunt and may account for their likelihood in presenting with a true shunt infection(6-7).Despite the number of procedures, the risk factors are unknown (6).Young age, especially prematurity, predisposes to higher shunt infection rates (6).Role of surgeon's experience, type of shunt, duration of procedure all are unknown (7).Most shunt infections occur within 2 months of shunt insertion. 80% will present within three months and 90% within six months. Shunt infection best classified by site: infected shunt hardware, wound infection, meningitis, and peritonitis (8).Shunt aspiration is highly diagnostic (95% accurate). Lumbar puncture or ventricular tap is less sensitive (7-26% accurate) but is usually a reasonable preliminary step. Obtaining CSF via lumbar puncture prevents the theoretical risk of shunt contamination by tapping (30).Routine CBC may demonstrate a leukocytosis. Blood cultures are only necessary if the patient is febrile (8).Sustained elevation of serum levels of C-reactive protein (CRP) after shunt insertion correlates strongly with the presence of shunt infection (8).Highly sensitive CRP (hs-CRP) is more sensitive than CRP as indicator of infection at a very earlier stage.CSF eosinophilia >7% of total CSF white cell count also correlate with shunt infection (8).An imaging study of the head (usually CT scan) is the first step in order to determine if hydrocephalus is present. Generally, infection will eventually cause shunt obstruction. Plain films are obtained to determine if the tubing is intact(9). An abdominal ultrasound or CT scan should be done if abdominal pain or a mass is present (9).Shunt removal, insertion of external ventricular drainage (EVD), and intravenous antibiotics carry high cure rate. Antibiotics alone carry a low cure rate. Although the exact time of externalization is unknown, most authors recommend at least a week of sterile CSF results. The CSF should be sampled from the EVD at least every other day to ensure that CSF sterility is being achieved (4).Exceptions to the principle of hardware removal are infection with H. influenza, meningococcus, and pneumococcus who can be cured with antibiotics alone. The CSF should be sampled during and after treatment to ensure that the infection has been cleared (4).An abdominal pseudocyst is treated by externalization of the distal catheter and antibiotics. Percutaneous aspiration of the cyst is only required if the cyst does not respond to antibiotics. Open laparotomy and drainage is virtually never required (5).In case of presence of intra-abdominal pathology, contamination of the shunt can occur from other general surgical procedures, such as insertion of a gastrostomy with peritoneal shunts. If a patient presents with obvious peritoneal sepsis (e.g., ruptured appendicitis or perforated bowel), it is generally accepted practice to externalize the shunt by making an incision over the chest wall (i.e., distal to the valve) and connecting the catheter to an external ventricular drainage (8). The aim of the article was to review the experience in a 2-year teaching hospital and to evaluate the risk factors for PV shunt failure after initial shunt surgery and after subsequent reviews.

Methods

The study was carried out at the Emergency Teaching Hospital in Duhok City in Iraq. All complications of VP shunted patients admitted in the hospital from Jan.2013 to Jan.2015, included in the study.The relevant information such as age, sex, residence, clinical feature, date of first shunt insertion, was obtained from case sheets.Forty-sixpatients are included in this study, with all shunt related complications.

Participants

Forty-six VP shunt revision operations done, 6 patients get more than one VP shunt revision operation.In this study, a complication is therefore defined as an unwanted event related to the surgical procedure that adds a pathological condition such as an infection or a hematoma to the patient's clinical status. Shunt failure (dysfunction, malfunction), on the other hand, is defined as a lack of function or insufficient function within any part of the shunt system, necessitating revision of the shunt. The case population consists of (46) patients with VP shunt complications (24 males, 22 females; age range from few days to (67 years), with mean age (8.65) years.The patients have been grouped according to etiology(Table 4).In all patients, the ventricular catheter was inserted either via a right posterior parietal area or a right frontal area. The scalp was shaved, but no adhesive covering was used over the skin. Care was taken to avoid allowing any implanted material to cross skin incisions. The peritoneum was opened via a right paramedian incision except for five cases in which left paramedian incision was used due to presence of excessive adhesions after opening a previous right side incision.Identification of patients with complications of VP shunt is done by obtaining history of deterioration of conscious level, signs and symptoms of infection, epilepsy, progressive enlargement of the head, poor feeding, also identification of ventricular enlargement with periventricular edema on imaging (brain CT or MRI), and identification of any evidence of device migration by chest and abdominal X-ray.Those patients in whom the professional diagnosis was shunt infection, CSF examination done and the results revealed elevated protein level, low sugar and high white blood cells count.

RESULTS

Distribution of patients with VP shunt revision by gender

This study showed that (52.2%) of patients were males and (47.8%) were females, male to female ratio was 1.1:1(Table 1).

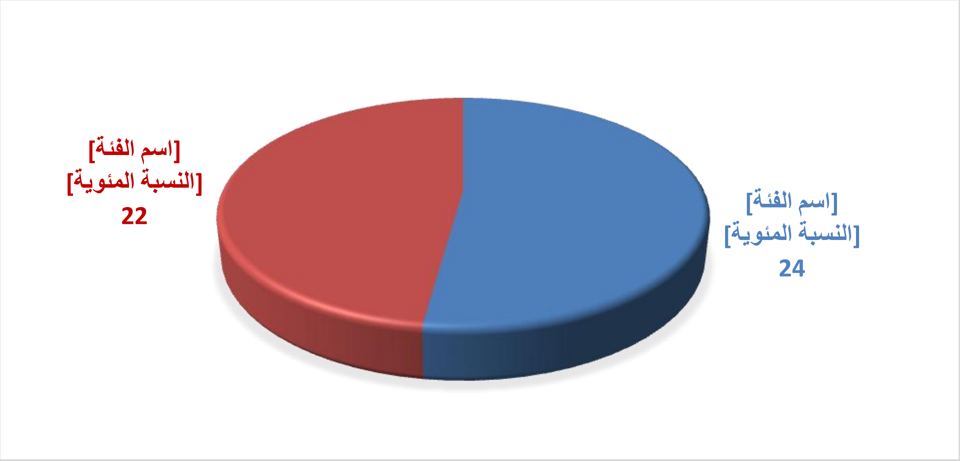

Fig 1: Distribution of patients with VP shunt revision by gender

Age distribution

This is shown in table 1; the mean age was 8.65 years in pediatrics and mean age was 28.65 in adults.

Table 1. Age distribution

age	***Number of patients***	***%***
Pediatric (younger than 15 years)	41	89.1
age	***Number of patients***	***%***
Adults (15 years and older)	5	10.9

The initial cause for VP shunt insertion

In this study, the initial cause for VP shunt insertion was congenital hydrocephalusin 34 patients (73.9%) and acquired hydrocephalus in 12 patients (26.1%). Among acquired hydrocephalus, 6 patients had Post meningitis hydrocephalus, 2 patients had Brain tumor, 2 patients had Intracranial hemorrhage, 1 patient had Post traumatic hydrocephalus and 1 patient had normal pressure hydrocephalus (Table 2).

Table 2. The initial cause for VP shunt insertion for the patients.

Cause		Number of patients	
Congenital		34 (73.9%)	
Acquired	Post meningitis hydrocephalus	6 (50%)	12 (26.1%)
	Brain tumor	2 (16.7%)	
	Intracranial hemorrhage	2 (16.7%)	
	Post traumatic hydrocephalus	1 (8.3%)	
	Normal pressure hydrocephalus	1 (8.3%)	
	Total	12 (100%)	
Total		46 (100%)	

Mean duration to develop complication of VP shunt after insertion

This studyfor all patients has shown that 34.8% of the complications (16 patients) occur within the first three months after shunt implantation, 50% of the complications (23 patients) occur within the first 6 months after shunt implantation, and 58.6% of the complications (27 patients) occur within the first year after shunt implantation.

Table 3. Mean duration to develop VP shunt complications after implantation.

Mean duration to develop VP shunt complications in months	**%**
First 3 months post op.	34.8 %
First 6 months post op.	50 %
First year post op.	58.6 %

Presenting symptoms and signs of VP shunt complications

This study has shown that the symptoms and signs expressed by the patients with VP shunt complications were as following decrease feeding or oral intake, headache, vomiting, decrease level of consciousness, seizure, and fever (Table 4, 5).

Table 4. Presenting symptoms expressed by pediatric patients in this study.

Presenting symptoms	Number of patients	%
Decrease feeding or oral intake	32	78
Head ache	20	48.8
Vomiting	16	39

Enlargement of the head	12	29.3
Decrease level of consciousness	9	22
Seizure	7	17.1
Fever	3	7.3

Table 5. Presenting symptoms expressed by adult patients in this study.

Presenting symptoms	Number of patients	**%**
Head ache	4	80
Vomiting	3	60
Decrease level of consciousness	3	60
Decrease feeding or oral intake	3	60
Fever	1	20
Seizure	1	20
Enlargement of the head	0	0

The study showed that most common complications in adult patients are obstruction by choroid plexus (3 patients) and shortening of the distal catheter due to growing of the patients (2 patients). While in children 15 patients out of 41 patients get obstruction by choroid plexus, 5 patients get obstruction by thick protein containing CSF, 9 patients out of 41 patients get infection, 3 patients get skin sloughing over the device, 1 get device migration, 1 get over drainage, 1 get IVH, CSF leak in 1 patient, SDH in 1 patient.

There were two cases with technique error (extra-peritoneal insertion of the distal catheter).Table (6).

Treatment options

The treatment options offered to the patients in this study were shunt change in 31 patients (67.4%), removal of the whole system in 6 patients (13%), Resiting of the ventricular or peritoneal catheter in 5 patients (10.9%) and Shunt externalization in 4 patients (8.7%). Table 7.

Table6. Type of complications

Type of complications		**Number of children patients**	**Number of adult patients**	**%**
Obstruction	By choroid plexus (72%)	15	3	54.3

(25) patients	By thick high protein containing material (20%)	5	0	
	By blood (8%)	2	0	
Infection (9) patients	*E. coli* (44.4%)	4	0	19.6
	S. epidermidis (22.2%)	2		
	S. aureus (22.2%)	2		
	Klebsiella sp. (11.1%)	1		
Skin sloughing over the device		3	0	6.5
Tube is extra-peritoneal		2	0	4.3
Shortening of the distal catheter		0	2	4.3
Device migration		1	0	2.2
Over-drainage (slit ventricle syndrome)		1	0	2.2
IVH		1	0	2.2
CSF leak		1		2.2
SDH		1		2.2
total		41	5	100

Table 7. Treatment options offered for the patients with VP shunt complications

Treatment options		**Number of patients**	**%**
Shunt change (31) patients	Whole system change 48.4%	15	67.4
	Device and ventricular catheter change 35.5%	11	
	Distal catheter change 12.9%	4	
	Ventricular catheter change 3.2%	1	
Removal of the whole system		6	13
Resiting of the ventricular or peritoneal catheter		5	10.9
Shunt externalization		4	8.7
Total		46	100

FIG 2: Black arrow shows ventricular catheter migrated outside the ventricle

FIG 3: Shows CSF collection under the skin at the site of parieto-occipital burr hole.

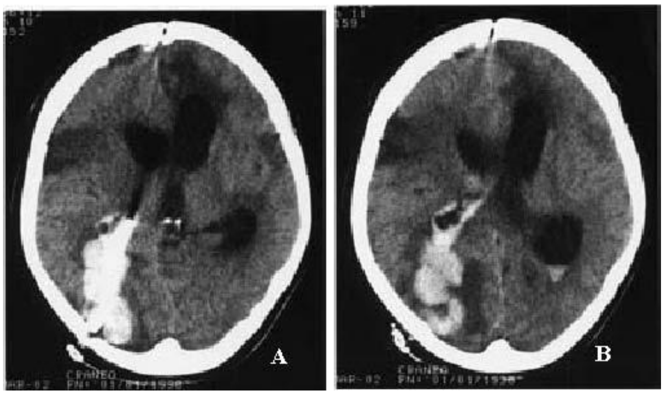

FIG 4: Brain computed tomographic scan showing an intraventricular hemorrhage after VP shunt revision.

FIG. 5. Distal catheter exposure.

Discussion

Ventriculoperitoneal (VP) shunt surgery is the predominant mode of therapy for patients with hydrocephalus. However, it has potential complications that may require multiple surgical procedures during a patient's lifetime.In this study the incidence of the complications was (27.1%); forty six patients got complications out of (170 patients with ventriculo-peritoneal shunt operations, which is consistent with the finding of others(10-11).The findings of the study reveal that male patients had little bit greater rates of shunt revision than female patients (52.2% vs. 47.8%), which is consistent with other researchers (10).The role of age at the time of first shunt insertion has been evaluated previously in several studies. In the Cooperative Survey of the 1991 -1992 Education Committee of the International Society of Pediatric Neurosurgeons (ISPN) (12), the authors noted that there was a higher rate of failure among patients in whom shunt implantations were performed at less than 6 months of age. In keeping with the above study, our findings which had revealed that pediatric patients had significantly greater rates of shunt revision than adult patients (65.2% of the complications occur in patients with age below 6 years vs. 34.8% incidence of complications in patients above 6 years old), which is also consistent with the finding of others (10).Furthermore, the rate of complication, in the current study, is highest within the first six months after VP shunt insertion (50%), which is consistent with the finding of others (2).Much controversy surrounds the effect of cause of hydrocephalus on shunt failures. Three reports have suggested that intraventricular hemorrhage, tumor, and neural tube defects appear as significant contributors to shunt failure(13-15). This study also shows that the development of complications depends on the initial cause for the VP shunt insertion; incidence of VP shunt complication is higher in patients with congenital hydrocephalus vs. acquired hydrocephalus (73.9% vs. 26.1%), and among patients with acquired hydrocephalus, the incidence of complication is least for post traumatic hydrocephalus and normal pressure hydrocephalus. All these findings are consistent with the finding of other researchers (2,10,16).The study also revealed that the most common symptoms and signs in pediatric age group (age younger than 15 years old) were decrease feeding or oral intake (32 patients, 78%), headache (20 patients, 48.8%), vomiting (16 patients, 39%), enlargement of the head (12 patients, 29.3%), decrease level of consciousness (9 patients, 22%), seizure (7 patients, 17.1%), and fever (3 patients, 7.3%). However, in adult patients, the study revealed that the most common symptoms and signs were headache (4 patients, 80%), vomiting (3 patients, 60%), decrease level of consciousness (3 patients, 60%), decrease oral intake (3 patients, 60%), fever (1 patient, 20%), and seizure (1 patient, 20%), findings which were consistent with others' findings(10,16-17).The two main VP shunt complications in this study were obstruction

(25 patients, 54.3%) and infection (9 patients, 19.6%) respectively, these findings were consistent with the finding of others (2,10,17).Regarding shunt obstruction, it has been found in this study group that proximal catheter occlusion was the largest cause of shunt failure (18 patients, 72%). The majority of our shunts had occipital proximal catheters, which may have contributed to the occlusion rate. There are conflicting data in the literature regarding which cortical entry site provides the lowest occlusion rate (18). Theoretically, a large portion of shunt failures may be averted by any technique that reduces the tendency of the proximal catheter to become occluded with choroid (19).Placement of the ventricular catheter is important factor; in general it should be put away from the choroid plexus and in area where the ventricle is believed to remain for great even after CSF diversion (11). Occurrence of slit ventricle is about 40% in some series. Use of valve system with antisyphoning characteristics to reduce over drainage is important to reduce incidence of slit ventricle (20).Programmable valves can be adjusted noninvasively to vary resistance to outflow across a physiologically normal range. Two clinical observations drove the development of variable-pressure programmable valves. The first was that a significant (although smaller than with fixed-pressure valves) subset of patients treated with flow-regulated valves suffered from chronic headache. The second was the belief among selected groups of neurosurgeons that the ideal outflow resistance for an individual patient was a dynamic rather than a static system (3).The distal catheter is by far the largest and longest component of a ventricular shunt, but it generally functions the best and has the fewest problems of all the shunt components. The most common problem related to distal catheter function is fracture of the catheter, mostly between the mastoid and the clavicle (2). Disconnection is best prevented by careful technique (21). Alternatively may also pull out of the atrium or peritoneum with growth of the patient, or an infected pseudocyst may develop around the distal catheter tip, or may descend down a hernia or varicoceles with migration of the distal catheter into the scrotum of a male patient (2). Migration is prevented by using valve system that prevents the movement of the system through the soft tissue. Over dissection of the soft tissue should be avoided (22). Barium impregnation allows the catheter to be visualized radiographically and fractures or placement problems (23). Both the ventricular and distal catheters may be impregnated with antimicrobials that are gradually released into the local tissue in the days or weeks after shunt implantation. Rifampin and clindamycin are the most commonly used antibiotics that are directly impregnated into the shunt system (Codman Bactiseal System R) (24).Shunt infections can complicate otherwise successful treatment of hydrocephalus, leading to increased healthcare costs and patient morbidity, or even mortality.Regarding infection as a VP shunt complication, the most commonly found infectious agent is

Escherichia Coli, the finding which is inconsistent with many other reports (2,10,16). This finding may be due toimproper disinfectant procedures and policy at our hospital, and the lack of operative theatre standardizations.The risk of device migration and shortening of the distal catheter is more common in older patients(25). All cases of device migration and shortening of the distal catheter were in patients older than 10 years. This might be due to growth process. It's suggested to well fix the device to the surrounding tissue and the length of the intraperitoneal part of the distal catheter to be atleast20 cm.Since most of the complications, in the current study, was due to obstruction, the treatment option offered to patients was change of the shunt system (31 patients, 67.4%).. The second treatment option was removal of the shunt system (6 patients, 13%) and externalization of the shunt (4 patients, 8.7%). This latter optionwas given to patients with VP shunt infection. These findings were consistent with other researchers (10,26).The largest limitations of this study are its retrospective nature, small study group, those patients who were lost to follow-up or died, and the short study period. This could artificially affect the revision rate by omitting either the patients who did well, and therefore did not present for follow-up, or those who left our hospital and received care elsewhere.When performing this procedure,the level the drain should be placed at is 0 cm above the foramen of Monro because the valve will still be functioning. Reinternalization should be performed only when the intra-abdominal sepsis has been eradicated. If there is a high chance of bowel adhesions, it may be more prudent to convert to a ventriculopleural or ventriculoatrial shunt (8).Shunting of the CSF leads to negative intracranial pressure; the lower pressure in the ventricles creates a pressure gradient across the subdural and the subarachnoid spaces, which results in opening of the subdural space (22). Certain individuals are at higher risk (22): Those with cortical atrophy, those with longstanding hydrocephalus, and patients with normal pressure hydrocephalus (NPH) (20-40%).In high risk patients, one may consider putting a shunt device with antisiphon, minimal CSF should be removed at the time of surgery, and post operatively the patient should be kept flat and elevated gradually (22).Once subdural collection developed, upgrade the valve pressure. Subdural collection usually drained or shunted at the same time (22). This did not occur in the current study.Shunting can create very negative intracranial pressure; especially in the setting of longstanding hydrocephalus, the skull base can be thinned, increasing the chance of communication between the sinuses and the subdural space (27) (pneumocephalus). Also, although rare, craniosynostosis, premature closure of the cranial sutures may result from shunting of CSF (28); none of the aforementioned complications had occurred with this study.Complications of shunts for posterior fossa masses are: Upward cerebellar herniation, infection, tumor hemorrhage, abdominal complication, and an increased risk of extra neural metastasis(3). Malignant cell metastasis, most common source is medulloblastoma; millipore filter analysis has revealed tumor cells trapped in the filter. This filter rarely used due to frequent obstruction(28); luckily, none occurred in the present study.

Conclusions:

The findings of the study indicate that age of the patient at time of shunt placement, etiology of hydrocephalus, and previous treatments before shunt surgery were independently significantly associated with the shunt survival. Prospective controlled studies are required to address the observed associations between the risk factors and incidence of shunt revisions in these patients.

<u>References</u>

1. Ardan A. Sulaiman: Hydrocephalus. A thesisSubmitted to the Iraqi Board for Medical Specialization 2010; 1-24.
2. Aabir Chakraborty, James M. Drake, Benjamin C. Warf. Methods for Cerebrospinal Fluid Diversion in Pediatric Hydrocephalus. In: Henry H. Schmidek, David W. Roberts (eds). Schmidek & Sweet Operative Neurosurgical Techniques. 6th edition. Philadelphia: Saunders 2012: 631-653.
3. Jeffrey P. Blount. Ventricular Shunting Procedures. In: H. Richard Winn (eds). Youmans Neurological Surgery.6th edition. Philadelphia: Saunders 2011: 2009-2018.
4. Rymarczuk, George N., et al. "A comparison of ventriculoperitoneal andventriculoatrial shunts in a population of 544 consecutive pediatricpatients." Neurosurgery 87.1 (2020): 80-85.
5. Harischandra, L. S., Anurag Sharma, and Sandip Chatterjee. "Shunt migrationin ventriculoperitoneal shunting: A comprehensive review ofliterature." Neurology India 67.1 (2019): 85.
6. Fux CA., Quigley M., Worel A.M. Biofilm-related infections of cerebrospinal fluid shunts. Clin Microbiol Infect 2006; 12: 331-337.
7. O’Gara J.P. biofilm mechanisms and regulation in Staphylococcus epidermidis and Staphylococcus aureus. FEMS Microbiol Lett 2007; 270: 179-188.
8. Jeffrey M., Tessier W., Michael Scheld. Basic Science of Central Nervous System Infections. In: H. Richard Winn (eds). Youmans Neurological Surgery.6th edition. Philadelphia: Saunders 2011: 544-559.
9. Sivaganesan A., Krishnamurthy R., Sahni D.Neuroimaging of ventriculoperitoneal shunt complications in children. Pediatr Radiol 2012; 42: 1029-1046.

10. Kesava G. Reddy, Papireddy Bollam, Gloria Caldito. Long-term outcomes of ventriculoperitoneal shunt surgery in patients with hydrocephalus. World Neurosurg (2014) 81; 2: 404-410.
11. Peter Lee, Arthur J., DiPatri Jr. Evaluation of suspected cerebrospinal fluid shunt complications in children. Clin Ped Emerg Med 2008; 9: 76-82.
12. Piatt JH. Jr., Carlson CV. A search for determinants of cerebrospinal fluid shunt survival: retrospective analysis of a 14-year institutional experience. Pediatr Neurosurg 1993; 19: 233-242.
13. Cozzens JW., Chandler JP. Increased risk of distal ventriculoperitoneal shunt obstruction associated with slit valves or distal slits in the peritoneal catheter. J Neurosurg 1997; 87: 682-686.
14. Serlo W., Fernell E., Heikkinen E. Functions and complications of shunts in different etiologies of childhood hydrocephalus. Childs Nerv Syst 1990; 6: 92-94.
15. Liptak GS., McDonald JV: Ventriculoperitoneal shunts in children: factors affecting shunt survival. Pediatr Neurosci 1985; 12: 289-293.
16. Husham shaker. Complications of ventriculoperitoneal shunt. A thesisSubmitted to the Iraqi board for medical specialization 2005; 1-40.
17. Farid Khan & Muhammad Shahzad Shamim. Analysis of factors affecting ventriculoperitoneal shunt survival in pediatric patients. Childs Nerv Syst (2013) 29:791–802.
18. Farahmand D., Hilmarsson H., Högfeldt M., Tisell M. Perioperative risk factors for short term shunt revisions in adult hydrocephalus patients. J Neurol Neurosurg Psychiatry 2009; 80:1248–1253.
19. Sarah C. Jernigan, Jay G. Berry. The comparative effectiveness of ventricular shunt placement versus endoscopic third ventriculostomy for initial treatment of hydrocephalus in infants. J Neurosurg Pediatrics 2014; 13: 295-300.
20. Epstein F., Lapras C., Wisoff J.H: Slit ventricle syndrome. Etiology and treatment. Pediatric Neuroscience 1988; 15: 5-10.
21. Kesava G, Reddy, Papireddy Bollam, Gloria Caldito. Long-term outcomes of ventriculoperitoneal shunt surgery in patients with hydrocephalus. World Neurosurg (2014) 81; 2: 404-410.
22. Sagun Tuli, M.D., James Drake. Risk factors for repeated cerebrospinal shunt failures in patients with hydrocephalus. Neurosurg Focus (1999) 7: 1, 1-12.
23. Broggi, Morgan, et al. "Diagnosis of Ventriculoperitoneal Shunt Malfunction: APractical Algorithm." World Neurosurgery (2020).

24. Kestle J., Drake J., Milner R. Long-term follow-up data from the Shunt Design Trial. Pediatr Neurosurg 2000; 33:230.

25. Farid Khan, Muhammad Shahzad Shamim, Abdul Rehman. Analysis of factors affecting ventriculoperitoneal shunt survival in pediatric patients. Childs Nerv Syst 2013; 29: 791–802.

26. Kai Rui Wan, Jennifer Ah Toy, Rory Wolfe, and Andrew Danks. Factors affecting the accuracy of ventricular catheter placement. Journal of Clinical Neuroscience 2011; 18: 485–488.

27. Jonathan J., Stone, M.D., Corey T., Walker. Revision rate of pediatric ventriculoperitoneal shunts after 15 years. J Neurosurg Pediatrics 2013; 11: 15–19.

28. Abhaya V., KulKArni. Outcomes of CSF shunting in children: comparison of Hydrocephalus Clinical Research Network cohort with historical controls. J Neurosurg Pediatrics 2013; 12: 334–338.