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Ventriculoperitoneal Shunt Failure in Pediatric Patients with Hydrocephalus

Alaa A. Farg MD, Ahmed Sleem MD,
Nasser M Sayed Ahmed MD and Fathy Elnos MD
Department of Neurosurgery, Benha University Hospital

ABSTRACT

Objective: *Despite advances in cerebrospinal fluid (CSF) diversionary techniques, shunt failure due to infection or malfunction remains a persistent problem in hydrocephalus care. The aim of this study was to identify risk factors predisposing to repeated CSF shunt malfunction and to determine whether subsequent shunt failures are related to patient characteristics, and/or surgical details.* ***Patients and Methods:*** *There were 195 shunt failures in 130 patients with hydrocephalus requiring CSF diversionary procedures were included in a prospective observational study during 9 years in Benha University Hospital. Patient characteristics were defined as age, gender, weight, head circumference, cause of hydrocephalus; and the shape of ventricular systems. Surgical details and procedures were studied to define any relation to the incidence of shunt failure.* ***Results:*** *The patient's age at the time of initial shunt placement is important predictor of repeated shunt failures. There were significant association between the cause of hydrocephalus, and the shape of ventricular system; and shunt failure. Some surgical details and procedures were associated with an increased risk of failure included whether the procedure was performed on an emergency or non-emergency basis, manipulation of the shunt hardware; and the duration of surgical procedure.* ***Conclusion:*** *The patient's age at the time of initial shunt placement as well as the cause of hydrocephalus and the shape of ventricular system are important predictors of shunt failures. Some surgical procedures were associated with an increased risk of shunt- related failure. Prevention and early identification and management of CSF shunt failures remain the main factors to assure the quality of the patient's long term outcome.*

Key Words: *hydrocephalus-cerebrospinal fluid shunt failure–revision of ventriculoperitoneal.*

INTRODUCTION

Nulsen and Spitz[21] described the first workable extracranial CSF shunt in 1952. Since then, shunts have revolutionized the treatment of hydrocephalus and other disturbances of CSF flow dynamics[11]. Cerebrospinal fluid (CSF) shunt failures in pediatric patients are common, causing morbidity ad occasionally mortality. Ventriculoperitoneal shunts are associated with several complications as shown in table (1). Following initial shunt insertion, the failure rate by 1 year post implantation is 25 to 40 %[12] and a 2-year failure rate of greater than 40%[14]. The 10-year survival of a first CSF shunt is reported to be 30 to 37%[3,27]. These devices are usually required for the duration of the patient's life and in most cases there is more than one episode of shunt failure. Various risk factors for CSF shunt failure have been indicated in the literatures table (2). Even recent technological advances in shunting, such as variable pressure valves, flow control valves, antibiotic impregnated tubing, and endoscopic placement techniques, have failed to resolve frustration over the inability of shunts to provide reliable, uncomplicated CSF diversion[26,29]. The aim of this study was to identify risk factors predisposing to repeated CSF shunt malfunction and to determine whether subsequent shunt failures are related to

patient characteristics, and/or surgical details.

PATIENTS & METHODS

From January 1997 to January 2006 prospective observational studies of CSF shunt revisions were conducted to evaluate the risk factors predisposing to shunt failure, at Benha University Hospital. Patients were considered eligible for this study if they were undergone revision of CSF shunt at our department through a ventriculopertitoneal type. Patients who have undergone a CSF shunt procedure outside our department were excluded.

Patients with hydrocephalus were grouped into categories based on cause: aqueductal stenosis, intraventricular hemorrhage (IVH), psotmeningitic, post–traumatic and other table (3). Risk factors included those related to the patient's characteristics, intra-operative details and postoperative variables were obtained from the prospective medical records and anesthetic sheet table (4).

All patients underwent follow up in outpatient's clinic at 2 weeks, 1 month, 3 months, 6 months and at least one year postoperatively. The majority of CSF shunt failures are diagnosed at this time. The common causes of shunt failure are malfunction and infection. Malfunction was defined as the occurrence of symptoms in the presence of elevated intracranial pressure, as detected with shunt tap, or neuroimaging evidence of ventricular enlargement. Infection was defined as the occurrence of symptoms in the presence of a positive CSF shunt tap. The causes of shunt failure are categorized as shown in table (5). For each patients repeated shunt failure were identified and the risk factors determined. Each shunt failure was indexed as a failure level (that is 1,2, and 3) according to whether it was the first, second, or third episode of failure.

Table (1): Manifestations of CSF shunt failure

1-Mechanical malfunction (about 50% of cases)
- *Obstruction of →
  - Ventricular end
  - Valve
  - Distal end
- *Disconnection of the tube →
  - proximal to valve
  - Distal to valve

2-Infection (about 5-8%) of cases)
3-CSF over drainage
- *Acute →
  - Epidural hematoma
  - Subdural hematoma
- * Chronic →
  - Subdural hematoma
  - Subdural hygroma

4-Post-shunt craniosynostosis
5-Pneumocephalus
6-Epilepsy
7-Isolated ventricle
8-Complications unique to peritoneal shunt
- *Inguinal hernia and/ or hydrocele
- *Pseudocyst
- *Ascitis
- *Visceral perforation
- *Migration or extrusion

Table (2): Risk factors related to shunt failure

1-Preoperative variables
- *Patient characters
  - -age
  - -sex (M/F)
  - -Weight (kg)
  - -Head circumference (HC)
- *Cause of hydrocephalus
  - -IV hemorrhage
  - -aqueduct stenosis
  - -tumors
  - -meningitis
  - -trauma
  - -others
- *Ventricular system
  - -Congenital anomalies
  - -Loculated ventricles
- *Type of operation
  - -emergency
  - -With other surgical procedures

2-Intraoperative variables:
- *Prophylactic antibiotics
- *Operative time (minutes)
- *Time of opening shunt system
  - -Immediately pre-insertion
  - -With other surgical instruments
- *Handling of shunt system
  - -One person
  - -More than one person
- *Abdominal incision
  - -Midline
  - -Paramedian
- *Skull burr hole
  - -Occipital
  - -Others

3-Postoperative variables:
- *CSF leak from wounds
- *Premature stitches removal
- *Post-operative hospital stay

Table (3): Preoperative variables related to shunt failure

Characters	1st failure 80 patients	2nd failure 35 Patients	3rd failure 15 Patients
Clinical characters			
Age / month (mean)	3-84 (42)	1-46 (28)	0-13 (5)
Sex (x male)	46	18	9
Weight /kg (mean)	4-23 (17)	3.7-16 (12)	1.2 - 6 (4)
Head circumference (cm)	37-52 (43)	36 -54 (46)	37 – 58 (51)
Cause of hydrocephalus			
Aqueduct stenosis	29 (36%)	9 (26%)	3 (20%)
Myelomeningocele	31 (39%)	19 (54%)	9 (60%)
Intraventricular hematoma	6 (7.5%)	5 (14%)	3 (20%)
Meningitis	9 (11%)	1 (3 %)	--
Trauma	3 (4 %)	1 (3 %)	--
Others	2 (2.5 %)	--	--

RESULTS

During the study period, 195 shunt revisions due to failure of their shunt system were performed in total 130 patients. Complete follow up data were obtained for all patients. The pre-operative variables related to shunt failure are mentioned at table (3). The most common patient's characteristic factors related to shunt failure were the age followed by weight and head circumference of the patients. The incidences of the most common causes of hydrocephalus related to 2nd shunt failure were myelomeningocele (54%), aqueduct stenosis (26%), intraventricular hematoma (14%), and post-meningitic (3%) table (3). The surgical and post-operative variables relate to shunt failure are mentioned at table (4). With respect to the surgical procedure 23 to 40% of the cases were treated on an emergency basis. There were two postoperative very important variables related to the shunt failure, first one was CSF leak from the wound and the second was the time of hospital stay which had strong relation to shunt failure. The post-operative demonstrated causes related to shunt failure in the first time were as the following order, obstruction occurred in 65%, infection in 19%, over drainage in 7.5%. As the number of shunt failure increased, the proportion of cases in which obstruction occurred increased, and those of infection and over drainage decreased table (5).

Table (4): Surgical and post –surgical characters

Variables	1St failure 80 patients	2nd failure 35 Patients	3rd failure 15 Patients
Surgical			
Type of operation			
Emergency	24 (23 %)	10 (28.5%)	6 (40%)
Operative time by minute (mean)	25-120(77)	35–170 (122)	40 -180(130)
Time of opening shunt package			
Pre-insertion	62 (77.5%)	26 (74%)	12 (80%)
With surgical instruments	18 (22.5%)	9 (26%)	3 (20%)
Post-operative			
CSF leak	12 (15%)	12 (34%)	6 (40%)
Hospital stay > 3 days	56 (70%)	28 (80%)	13 (86.5%)

Table (5): Causes of shunt failure

Cause of failure	1St failure 80 patients	2nd failure 35 Patients	3rd failure 15 Patients
Obstruction	52 (65%)	26 (74%)	12 (80%)
Infection	15 (19%)	5 (14%)	2 (13.5%)
Over drainage	6 (7.5%)	2 (6%)	1 (6.5%)
Ventricular system anomalies	5 (6%)	1 (3%)	--
Others	2 (2.5%)	1 (3%)	--

DISCUSSION

Despite the evident benefits of CSF diversion, shunting remains plagued with a high complication rate[29]. Identification of risk factors, however, has been difficult because of the requirement of a large population of patients, who are required to undergo follow –up review for a considerable length of time. In this study we attempted to identify perioperative risk factors for CSF shunt failure by using careful prospective observation of shunt operation in children. In a number of previous studies the authors have evaluated risk factors contributing to shunt malfunction. These studies have essentially been descriptive or observational in nature, and interventional studies have been rare. There are many literatures on CSF diversionary procedures in children[2,4,6,10,17,24,25,28]. The role of age at the time of first shunt insertion has been evaluated previously in several observational studies [5,7,10,15,17,18,22]. In a retrospective study of 170 hydrocephalic patients with myelomeningocele, no statistically significant difference in risk of failure was demonstrated in those patients undergoing a first placement procedure at less than and greater than one week of age[5]. In our study the results indicate that age at the time of first shunt insertion proved to be an important contributor not only to the first failure but also to the subsequent failure levels. Weight and head circumference (HC) are clearly age-related factors in this patients who weighted less than 3000 gm had no statistically significant difference in the rate of infection, and there was a barely significant worse overall shunt survival rate among patients weighting less than 3000gm[17]. In 67 patients with neural tube defects, who underwent a total of 122 shunt procedures, HC at the time of shunt insertion did not correlated with shunt survival[16]. In this study the age of the patient was a better indication of patient maturity, because age was so highly correlated with weight and HC, and particularly HC may be influenced by the extent of hydrocephalus.

There is a general discrepancy within the literature regarding the effect of hydrocephalus origins on shunt survival. In an earlier study, ***Piatt and Carlson***[21] analyzed 727 shunt operations to determine predictors of shunt survival, and they found no relationship between hydrocephalus origins and the incidence of shunt complications. In a more recent study, ***McGirt and Colleagues***[19] evaluated shunt survival in 353 pediatric patients, and their results agreed with those of ***Piatt and Carlson***[21]. In contrast, several authors suggest that hydrocephalic origin does in fact affect shunt survival. In a 1995 study involving 105 pediatric patients, the authors demonstrated that patients with intraventricular hemorrhage have shorter shunt survival times than those without hemorrhage[29]. Furthermore, ***Quigley et al.*** [23] who examined 41 cases of CSF shunt infection, suggested that only intraventricular hemorrhage as an origin correlated with sepsis risk. An increased complication risk has also been associated with myelomeningocele. In a study of the CSF shunt infection risk, ***Enger and Coauthors***[13] determined that patients with myelomeningocele had a higher infection risk compared with patients with hydrocephalus due to other causes. Additionally, data from an earlier study of 431 patients with newly inserted CSF shunts revealed that patients with myelomeningocele were significantly more prone to infection than those with congenital hydrocephalus, thus high-lighting the potential effect of origins

on shunt survival[29]. Conversely, results of another study suggest that patients with neural tube defects have longer shunt survival times than patients with other disease origins[18]. Our findings revealed that IVH, postmeningitic, and myelomeningocele were a little significant causative factors in shunt failure.

In our study the presence of postoperative CSF leak was the strong risk factor for shunt failure, all the patients who suffered from CSF leak were underwent revision of their shunt, it represented about 40% as the causative factors in 3rd shunt failure table (4). ***Abhaya***[1] described the CSF leak as the strongest risk factor for shunt infection. Welch[30] reported CSF leak as the causative factor in 15% of shunt infection and Davis[9] described accumulation of CSF at the operative site as a potential risk factor. In most cases CSF accumulation indicate an underlying shunt infection, it may also act as a conduit for contamination of the underlying shunt system by external skin organisms, or it may act as a marker for poor wound healing, reflecting an increase risk for infection and failure of the shunt system. To avoid this complication meticulous opening of the dura, choice the site of insertion of the ventricular catheter and also the proper wound closure are highly important surgical procedures.

Perhaps the most interesting finding of the study is that the length of time from the previous shunt failure is an important risk factor for subsequent shunt failure. The ratio for the second and third episodes of shunt failure was approximately 1.5 times for shunts that failed within 6 months compared with those that failed after 6 months. The contribution of this factor remains essentially unchanged as the failure level increased, suggesting that the timing of a previous procedure is a fundamental component of repeated shunt malfunctions. ***Piatt***[20], ***Piatt and Carlson***[21] also noted an increased risk of failure for shunts that undergo revision in less than 6 months since implantation.

CONCLUSION

In conclusion, many risk factors had been identified for the development of CSF shunt failure. Age at first shunt insertion and associated congenital anomalies are most important patient-related predictors of repeated shunt failures. Great care should be taken intraoperatively to avoid a postoperative CSF leak. Surgeon and attendant personnel should minimize manual contact with the shunt system and consider the use of double gloves reduction of the hospital stay time should be considered. The timing of the previous shunt procedure is significant: a revision performed in less than 6 months results in an increased risk of failure.

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