

Ventriculoperitoneal Shunt Complication in Pediatric Hydrocephalus: Risk Factor Analysis from a Single Institution in Nepal

Abstract

Objective: Ventriculoperitoneal (VP) shunt surgery is one of the commonly performed neurosurgical procedures. Complications due to shunt failure are associated with high morbidity and mortality. We report an analysis of risk factors for shunt failure in pediatric patients from a single institution in Nepal. **Materials and Methods:** A retrospective analytical study with prospective data was designed. All children younger than 15 years, with first time VP shunting, at a tertiary government hospital in Kathmandu during 2014-2017 were followed up. Association of independent variables with the primary outcome variable (complication of VP shunt) was analyzed using Chi-square test. Bivariate logistic regression was performed to identify unadjusted odds ratio (OR) with 95% confidence interval (CI). Multivariate logistic regression model was designed to calculate adjusted OR with 95% CI. **Results:** Of 120 patients, more than half (55.8%) of the patients were male. Mean age was 62.97 months. Maximum duration of follow-up was 30 months. Most common cause of hydrocephalus was congenital aqueductal stenosis (40.8%) followed by tumors (29.2%). Overall shunt complication was found in 26.7% (95% CI 19.0%–35.5%). Shunt infection was seen in 5% while malfunction without infection was found in 21.7%. Bivariate logistic regression showed duration of surgery more than 1 h (OR 2.67, 95% CI 1.11–6.42, $P = 0.028$) compared to 1 h or less, experienced surgeon (OR 0.37, 95% CI 0.16–0.89, $P = 0.026$) compared to residents, and emergency surgery (OR 3.97, 95% CI 1.69–9.29, $P = 0.001$) compared to elective surgery as significant risk factors, while emergency surgery was the only significant variable for shunt failure on multivariate regression analysis (OR 3.3, 95% CI 1.16–9.35, $P = 0.025$). **Conclusion:** Longer duration of surgery, less experience of the surgeon, and the priority of the case (emergency) were independent risk factors for shunt complications.

Keywords: Hydrocephalus, infection, malfunction, pediatric, shunt

Introduction

Hydrocephalus (HCP) is a common neurosurgical disorder with an estimated prevalence and incidence of 0.9–1.2/1000 and 0.2–0.6/1000, respectively, in developed world.^[1] Although a reliable estimate is not available, the incidence is likely to be higher in developing countries.^[2]

Cerebrospinal fluid (CSF) shunt surgeries have dramatically reduced morbidity and mortality of children with HCP. However, these procedures are associated with potential complications such as infection and malfunction. In pediatric surgical series, shunt failures occur in 14% of patients just within the 1st month after shunt placement^[3] and 40%–50% of the shunts will fail within the 1st year.^[4,5] Shunt revision surgeries account for 48% of all

shunt-related procedures performed in the United States.^[6]

Lately, endoscopic third ventriculostomy (ETV) has emerged as an alternative to ventriculoperitoneal (VP) shunt for HCP. Absence of hardware makes ETV a viable alternative to shunting to reduce the complications of VP shunt. However, effectiveness of ETV in all etiologies and in all age groups has yet to be proven. Pan *et al.* found that the early risk of failure was significantly higher in ETV compared to shunt. The relative risk of ETV failure compared to shunt at 3 months of follow-up was 40% higher than shunt ($P = 0.011$).^[7] Further, due to availability of expertise, technology, infrastructure, and cost-related issues, VP shunt is still the most commonly performed and only

Prakash Paudel^{1,2},
Prakash Bista²,
Durga Prasad
Pahari³,
Gopal Raman
Sharma^{1,2}

¹Department of Neurosciences, Medciti Hospital, Lalitpur, Uttar Pradesh, India,

²Department of Neurosurgery, Bir Hospital, ³Department of Community Medicine and Public Health, Institute of Medicine, Tribhuvan University, Kathmandu, Nepal

Address for correspondence:

Prof. Gopal Raman Sharma,
Department of Neurosciences,
Nepal Medciti Hospital,
P. O. Box 44600, Sainbu,
Lalitpur, Nepal.

E-mail: gopal47@hotmail.com

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available option to treat HCP in low-resource setting like Nepal.

Early identification and management of risk factors may help in improving patient outcome. Here, we report our 4-year experience of management of pediatric HCP with VP shunts, their complications, and analysis of risk factors for shunt failure.

Materials and Methods

Study population

A retrospective analytical study of prospectively collected data was designed and conducted in the Department of Neurosurgery, National Academy of Medical Sciences (NAMS), Bir Hospital, Kathmandu, Nepal. All pediatric patients with HCP aged below or equal to 15 years who underwent first VP shunting and consented for participation in the study were included. Patients with prior VP shunt or those who had other diversion procedures (ventriculoatrial shunts, ventriculopleural shunts, or external ventricular drainage) than VP shunt were excluded.

Surgical procedure

VP shunt surgery was performed under general anesthesia (with endotracheal intubation) in an operation theater dedicated only for neurosurgical procedures. All elective VP shunt procedures were done as the first case of the day. The operative area was first cleaned with savlon solution, and then, the skin was meticulously prepped with povidone-iodine solution from scalp, neck, and upper chest down to the abdomen. After this, draping was done exposing the operative field. The number of scrubbing personnel in the operating room was limited to an operative surgeon, an assistant, a scrub nurse, a circulating nurse, and an anesthesiologist. Normal Chhabra shunt (nonantimicrobial impregnated) was used in all cases, which was assembled, immersed, and rinsed with 80 mg of gentamycin diluted in 100 ml of normal saline. Nontouch technique was used to avoid contact between the shunt and patient's skin, as well as the surgeon's gloves, using instruments, and clean gauze to handle the shunt components. Intravenous antibiotics were given before induction and continued for 1 week postoperatively.

Data collection and management

Ethical approval was taken from the Institutional Review Board of NAMS. Demographic details, clinical findings, and preoperative radiological imaging were obtained in all cases from medical records. Surgical variables were documented on a data sheet designed for the study. Computed tomography scan of head, clinical status, and CSF analysis reports were documented before discharging the patient. All the patients were evaluated for complications at the time of admission, at discharge, at routine outpatient department follow-up, and at emergency

department visits for shunt complications. All cases were consecutively identified between April 15, 2014, and May 6, 2017, and were followed up prospectively until the study closure on May 6, 2017. Any complication (either shunt infection and/or shunt malfunction) developed during the study period was documented by the investigation team members or neurosurgical residents.

Primary study outcome

The primary outcome was shunt infection or malfunction. As per previous literature,^[8] shunt infection was defined as the identification of a bacterial pathogen from the reservoir CSF or reservoir CSF pleocytosis (more than 50 leukocytes/cumm) in association with positive blood culture when a patient presents with any of the following after surgery: (1) fever – body temperature $>100.1^{\circ}\text{F}$, (2) neurologic symptoms – headache or vomiting or Glasgow Coma Scale ≤ 14 , (3) abdominal symptoms – pain abdomen or abdominal distension or abdominal tenderness, and (4) shunt malfunction. Any obstruction, overdrainage, or underdrainage of CSF and/or malposition and migration of shunt catheter after surgery were defined as malfunction.

Demographic variables

Age ≤ 15 years (dichotomized as infants versus other than infants) and sex.

Clinical variables

Etiology of HCP (categorized into four groups: congenital aqueductal stenosis, tumor, infection, and inflammatory and others. Others include benign cysts, Dandy–Walker malformation, neural tube defects, and posttraumatic HCP) and duration of illness (dichotomized to less than or more than 1 month).

Surgical variables

Surgeon's experience was defined as consultant versus resident on training, duration of surgery (dichotomized as less than or more than 1 h from skin incision to closure), and case priority (dichotomized as elective or an emergency surgery).

Statistical analyses

Dichotomous and categorical variables were reported using frequencies and percentages, while mean was reported in continuous variables. Stratification with respect to age, gender, duration of illness, etiology, duration of surgery, priority of case, and the surgeon's experience was done. Association of independent variables with the primary outcome variable (shunt complication) was analyzed using Chi-square test. Statistical significance was determined at $P < 0.05$. Bivariate logistic regression was performed to identify unadjusted odds ratio (OR) with 95% confidence interval (CI). Then, multivariate logistic regression model was designed for those variables with $P < 0.1$ at bivariate

level to calculate adjusted OR with 95% CI. Analysis was performed in SPSS 17 (IBM, Chicago, IL, USA).

Results

Demographic and clinical variables

Among 133 patients with first VP shunting followed up in the study period, 13 were lost to follow-up, so 120 patients were included in the analysis. Mean age was 62.97 months, with infants being the most common age group (30.8%). Males were more common than females. Congenital aqueductal stenosis (40.8%) was the most common cause of HCP followed by tumors and inflammatory causes. Majority of the procedures were performed by consultants (71.7%), duration of surgery was <1 h in 45%, and 61.7% of cases were done in elective basis. The mean length of follow-up was 16 months. Overall shunt complication was seen in 26.7% (95% CI 19.0%–35.5%). Five percent had shunt infection while shunt malfunction without infection was found in 21.7% [Table 1].

Distribution of complications according to demographic and clinical characteristics

More complications were seen among male (29.9%), among children other than infants (31.3%), and among tumor etiology (34.3%). Similarly, failure rates were higher

in cases done by resident doctors (41.2%), in cases who had duration of surgery more than 1 h (34.8%), and among emergency procedures (43.5%) [Table 1].

Risk factors analysis for ventriculoperitoneal complications

On bivariate logistic regression analysis, duration of surgery ($P = 0.028$), priority of case ($P = 0.001$), and surgeon experience ($P = 0.026$) were significantly correlated with outcome. On multivariate analysis, urgency of the case was only significantly associated with higher complications ($P = 0.025$) [Table 2].

Discussion

This study showed that one-fourth of the pediatric patients (26.7%) developed complications after VP shunting within 30 months of surgery. Shunt malfunction was more common than infection (21.7% vs. 5%). Complications were found to be more frequent among male, older children other than infants, tumor etiology, operation time more than 1 h, cases operated by resident doctors, and emergency procedures. Of them, surgeon experience, duration of surgery, and priority of case were significantly associated with failure. Shunt failure occurred as early as 1 week up to 30 months after surgery.

The overall shunt complication rate in our study (26.7%) was comparable or less than reported from the literature including that from developed world. Previous reported pediatric shunt failure rate was 30%–40% at 1 year and approximately 50% at 2 years.^[9-11] Shannon *et al.* found that almost half of the patients (49%) experienced one or more shunt failures within 2 years of follow-up.^[12] A multicentered prospective cohort study analyzing the risk factors for shunt malfunction in pediatric HCP reported 33.2% failure rate, 23% of them were due to infection.^[10] Another study from Pakistan reported shunt failure rate of 23% in mean follow-up of 11 months.^[13] In our study, shunt complication was 26.7% at mean follow-up of 16 months, of which 18.75% were due to infection.

The overall infection rate reported in the literature ranges from 3% to 15%.^[3,14-17] Shunt infection rate of 5% in our study was at internationally accepted level. HCP Clinical Research Network Quality Improvement Initiative reported an infection rate of 5.7% in 2011.^[14] The same research group introduced the new protocol to use an antibiotic-impregnated catheter (AIC) and found a new infection rate of 6% which was not different than their previous infection rate (5.7%) with or without AIC.^[18] In our series, normal catheter was used in all cases due to cost factors.

Majority of shunt infection occurs early after surgery. Choux *et al.* found that 90% of the infections occurred within the first 6 months.^[19] Another study by McGirt *et al.* found that infection was responsible for 45% of failures

Table 1: Distribution of complications according to patient characteristics

| Variables | Complications, n (%) | Total cases, n (%) |
|--------------------------------|----------------------|--------------------|
| Age | | |
| Infants | 6 (16.2) | 37 (30.83) |
| Older children (>1 year) | 26 (31.3) | 83 (69.16) |
| Sex | | |
| Male | 20 (29.9) | 67 (55.8) |
| Female | 12 (22.6) | 53 (44.2) |
| DOI | | |
| 1 month or less | 13 (27.7) | 47 (39.2) |
| >1 month | 19 (26.0) | 73 (60.8) |
| Etiology | | |
| Congenital aqueductal stenosis | 11 (22.4) | 49 (40.8) |
| Tumor | 12 (34.3) | 35 (29.2) |
| Infection and inflammation | 4 (21.1) | 19 (15.8) |
| Others* | 5 (29.4) | 17 (14.2) |
| Surgeon experience | | |
| Consultants | 18 (20.9) | 86 (71.7) |
| Residents | 14 (41.2) | 34 (28.3) |
| Duration of surgery (h) | | |
| ≤1 | 9 (16.7) | 54 (45.0) |
| >1 | 23 (34.8) | 66 (55.0) |
| Priority of the case | | |
| Routine | 12 (16.2) | 74 (61.7) |
| Emergency | 20 (43.5) | 46 (38.3) |

*Others include DW malformation, meningocele/myelomeningocele, and posttraumatic. DW – Dandy–Walker; DOI – Duration of illness

Table 2: Association of complication with demographic and clinical variables

| Variables | Bivariate regression analysis | | | Multivariate regression analysis | | |
|--------------------------|-------------------------------|-----------|-------|----------------------------------|-----------|-------|
| | Unadjusted OR | 95% CI | P | Adjusted OR | 95% CI | P |
| Age | | | | | | |
| Infants | 0.42 | 0.15–1.14 | 0.09 | 1.26 | 0.41–3.91 | 0.682 |
| Older children (>1 year) | 1 | | | 1 | | |
| Surgeon experience | | | | | | |
| Consultants | 0.37 | 0.16–0.89 | 0.026 | 1.08 | 0.36–3.21 | 0.877 |
| Residents | 1 | | | 1 | | |
| Duration of surgery (h) | | | | | | |
| ≤1 | 2.67 | | 0.028 | 2.35 | 0.93–5.95 | 0.069 |
| >1 | 1 | | | 1 | | |
| Priority of the case | | | | | | |
| Emergency | 3.97 | 1.69–9.29 | 0.001 | 3.30 | 1.16–9.35 | 0.025 |
| Routine | 1 | | | 1 | | |

OR – Odds ratio; CI – Confidence interval

within the 1st month.^[3] In our case, 87.5% of the infections occurred within first 2 months of surgery, 50% of them occurred in the 1st month. The most common organism was coagulase-negative *Staphylococcus* (50%), followed by *Staphylococcus aureus* (17%) which was similar as reported by previous studies.^[8]

We evaluated demographic, clinical, and surgical variables to find their association with shunt complications. Of these, surgeon experience, duration of surgery, and the priority of case were found to be significantly associated with shunt failure. Tuli *et al.* examined the effects of patient characteristics, shunt hardware, and surgical details in pediatric patients.^[5] Their findings suggested that age (prematurity and infants), certain etiology of HCP (intraventricular hemorrhage, postmeningitis, and tumor), and the concurrent other surgical procedures were significantly associated with increased risk of failure. Their study did not show any association with gender, American Society of Anesthesiologists class, emergency surgery, duration of surgery, use of prophylactic antibiotic agents, and shunt-related factors. Simon *et al.* found age (6–12 months), prior neurosurgery, and the presence of gastrostomy tube as independent risk factors for infection.^[20] Similarly, a multicenter prospective cohort study found that age younger than 6 months, cardiac comorbidity, and endoscopic placement were independent risk factors for failures, while other factors such as etiology, payer, center, valve design, valve programmability, the use of ultrasound or stereotactic guidance, and surgeon experience and volume were not associated with risk for failure.^[10] Our study could not detect the association of age with shunt survival. This could be because of low sample size and the fact that majority of the patients were other than infants. As reported by Riva-Cambrin *et al.* and in contrast to the findings of Tuli *et al.*, our findings did not show any relationship between etiology and the risk of shunt failure.^[5,10]

Although our study found surgeon experience, duration of surgery, and case priority as significant factors of

failure, there is no consistency in these associations in the reported literature. Omrani *et al.* and Griebel *et al.* found surgeon experience as a statistically significant predictor of complication,^[15,21] while others failed to find this association.^[10,22] Similarly, Tuli *et al.* and Griebel *et al.*'s study could not find the duration of surgery and emergency surgery as the significant predictors of failure.^[5,15]

Being a retrospective study, it has its own limitations. We did not evaluate the impact of comorbidity as well as any other concurrent operation or neurosurgical intervention before shunt which could have influenced the outcome. Some patients were lost to follow-up and status of their shunt could not be assessed. Although this is the first and largest study in Nepal to analyze risk factors of VP shunt complication, the small sample size may have affected in power of study to detect all statistical significance.

Conclusion

The overall shunt complication rate among pediatric patients with HCP who had their first VP shunt surgery was 26.7% (95% CI 19.0%–35.5%). Malfunction was more common than infection (21.6% and 5%, respectively). Logistic regression analysis showed that longer duration of surgery, less experience of the surgeon, and the priority of the case (emergency) were independent risk factors for shunt complication. A prospective cohort study with larger sample size is recommended for further analysis of risk factors which will help reduce morbidity and mortality associated with shunt failure.

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Conflicts of interest

There are no conflicts of interest.

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