Rate and Risk Factors of Early Ventriculoperitoneal Shunt Revision: A Five-Year Retrospective Analysis of a Referral Center

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■ BACKGROUND: **Cerebral shunts are the mainstay treatment of hydrocephalus. Because most previous studies have focused on factors related to long-term outcomes of shunt surgery, we aimed to assess the rates and causes of 30-day ventriculoperitoneal shunt (VPS) failure in a single referral center over 5 years in both adult and pediatric patients.**

■ METHODS: **Patients who underwent VPS surgery from February 2012 to February 2017 in Ghaem Teaching Hospital, Mashhad, Iran were evaluated retrospectively through clinical history, operative reports, imaging studies, and follow-up notes. Data of 12 possible factors related to shunt failure were collected comprising age, gender, household income, level of education, cause of hydrocephalus, causes of revision, type of failure, anatomic site, duration of operation, time of surgery, surgeons' level of expertise, and Glasgow Coma Scale (GCS) score.**

■ RESULTS: **Among 403 VPS placements, 121 VPS revisions were performed, and 82 eligible patients were included in the study (57.3% male and 42.7% female). The 30-day shunt failure rate was 24.4% among all revisions. Obstruction and malposition were the most common causes of early revisions. Six factors were statistically significant in the univariate analysis. After adjustment in a logistic regression model, 2 factors, namely surgeons' level of expertise (odds ratio, 10.33; 95% confidence interval, 1.08–98.80) and anatomic site of the shunt (odds ratio, 10.28; 95% confidence interval, 1.21–87.35) were associated with early shunt revision.**

■ CONCLUSIONS: **Shunt surgeries performed by junior residents and shunts placed in the frontal site were associated with early shunt failure.**

INTRODUCTION

Hydrocephalus is defined as the condition of an increased volume of cerebrospinal fluid in the central nervous system[1] and there are >380,000 new cases annually. The incidence of the disease is highest in the Latin American, Southeast Asian, and African regions and lowest in Canada and the United States.[2] The mainstay treatment of hydrocephalus is placement of a ventriculoperitoneal shunt (VPS). Approximately 30,000 VPS procedures occur annually in the United States. The estimated rate of VPS failure is 11%–25% during the first year after primary shunt insertion, and some f evidence shows that the number of shunt revisions is lower in adult patients than in pediatric patients.[3]

Common possible complications that can be accompanied by VPS are obstruction, infection, disconnection or fracture, pseudocyst formation, bowel perforation, bleeding from subcutaneous vessels, ventricular collapse, and leak from the puncture site.[3-5] These surgical complications require further surgical interventions and can result in a significant medical, economic, and social burden, which consequently leads to patient dissatisfaction.[6,7]

Although many studies have been conducted on shunt failure, most have investigated pediatrics, and few have looked at this problem among adults.[8-11] In addition, many of these studies have been performed in developed countries,[12] but the factors included

Key words
- Adult
- Complication
- Hydrocephalus
- Pediatric
- Revision
- Ventriculoperitoneal shunt

Abbreviations and Acronyms
GCS: Glasgow Coma Scale
VPS: Ventriculoperitoneal shunt

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might have a different priority compared with those in developing countries. Some studies have indicated that there is a significant association with shunt survival between cause of hydrocephalus, age at the time of shunt placement, previous treatments before shunt insertion, and type of hydrocephalus.[5,6,10,13] In the current study, we added some other factors that might affect shunt survival, including the level of education of the patient or caregiver, household income, and time of surgery. Because causes of late revision of VPS have already been studied and evidence concerning early related factors of shunt revision is still limited,[5-7,13-15] we aimed to assess the factors that might be related to shunt failure within the period of 30 days after surgery, in both adult and pediatric patients with hydrocephalus.

METHODS

Study Population and Collection of Data

This cross-sectional study was performed to assess rates and causes of early shunt revision of patients with hydrocephalus between February 15, 2012 and February 15, 2017 in Ghaem Teaching Hospital, Mashhad, Iran. In our study, cases of early shunt revision were assumed to include any patients who underwent reoperation within 30 days of the initial shunt placement or the last time of the revised shunt surgery, and reoperation after 30 days was considered late shunt revision.

We excluded patients with lumboperitoneal shunts, patients whose shunt was inserted at another hospital, and those with incomplete registration data. Among the patients who underwent VPS placement in our institution, 82 eligible patients were recruited to the study. Data related to clinical history, operative reports, imaging studies, and outcomes of the patients were collected retrospectively by reviewing the patients' charts and follow-up notes. We followed the STROBE[16] (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines to improve the quality of reporting.

Variables and Definitions

A total of 12 variables comprising age, gender, household income, level of education, cause of hydrocephalus, causes of revision, type of failure, anatomic site of the shunt, duration of operation, time of surgery, Glasgow Coma Scale (GCS) score, and surgeons' level of expertise were collected through the medical documents. Patients younger than 19 years on the date of surgery were considered as pediatric. Household income was categorized into low, middle, and high on the basis of individual or family monthly income. We gathered the level of education of the patients or their caregivers as a potential factor that may affect shunt survival. If the subject was 19 years old or younger, we considered their caregivers' level of education; otherwise, the level of education was attributed to the patient themselves. We divided the causes of revision into obstruction, malposition, disconnection, infection, and overdrainage. Obstruction was defined as a blockage of the catheter with debris, such as blood, proteinaceous fluid, or pieces of choroid plexus. Infection was defined as the occurrence of clinical symptoms in the presence of a positive cerebrospinal fluid culture obtained through lumbar puncture or shunt tap. Underlying causes of hydrocephalus were categorized as congenital malformation, neoplasm, brain hemorrhage, spinal dysraphism, infection, and normal pressure hydrocephalus. The duration of operation was defined as the time between skin incision and skin closure. In our institution, all patients undergoing VPS placement are given intravenous cefazolin prophylaxis before surgery. In addition, to reduce the probability of infection during operation, a minimum number of people were allowed in the operating theater, and signs forbidding entry were placed on the doors during the surgery. Our project was approved by the institutional review board of the Mashhad University of Medical Sciences, Mashhad, Iran. Because the analysis used anonymous data and patients' identities are nonidentifiable, no specific research ethics or information governance approval was required.

Statistical Analysis

All data were analyzed using SPSS version 16.0 (SPSS Inc., Chicago, Illinois, USA). Descriptive analysis was presented as mean ± standard deviation. χ^2, Fisher exact, and t tests were performed as appropriate for between-group comparisons. Statistical significance was considered at $P < 0.05$. Factors with P values <0.1 in the univariate analysis were selected for multivariate analysis in a logistic regression model.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author on request.

RESULTS

A total of 473 shunt placements were performed from February 2012 to February 2017; 403 were VPS and 121 patients (30%) underwent revision surgery because of shunt malfunction. We excluded patients with lumboperitoneal shunts, patients who underwent index shunt surgery in another hospital, and patients with incomplete data registry (Figure 1).

Eighty-two patients were included in this study; 47 were male (57.3%) and 35 female (42.7%). The mean age of the participants was 16.7 years (median, 6 years; range, 1 month—75 years). Distribution of other demographic data, including the level of education and household income, are listed in Table 1.

Congenital anomalies (36.5%) and neoplasms (23.1%) were the most common causes of hydrocephalus. In addition, brain hemorrhage (10.9%), spinal dysraphism (9.7%), infection (8.5%), and normal pressure hydrocephalus (7.3%) were other underlying causes of hydrocephalus and are listed in Table 2.

The most common cause of shunt revision was obstruction of the shunts, which occurred in 44 patients (53.6%), and malposition (13.4%), disconnection (12.1%), infection (4.8%), and overdrainage (4.8%) were other frequent causes of shunt revision (Table 2). We found that 24.4% of the cases developed early shunt revision, whereas the rate for late shunt revision was 75.6%. The results of the comparison of the early revision versus late revision surgeries are shown in Tables 3 and 4. Evaluation of the anatomic site between the 2 groups showed that 71.4% (5 of 7) of patients with frontal shunts had early revision, whereas this frequency among patients with occipital shunts was 20% (15 of 75) ($P = 0.008$). We also found that there is an apparent difference between early shunt revision rate of qualified neurosurgeons and neurosurgery residents ($P = 0.001$).

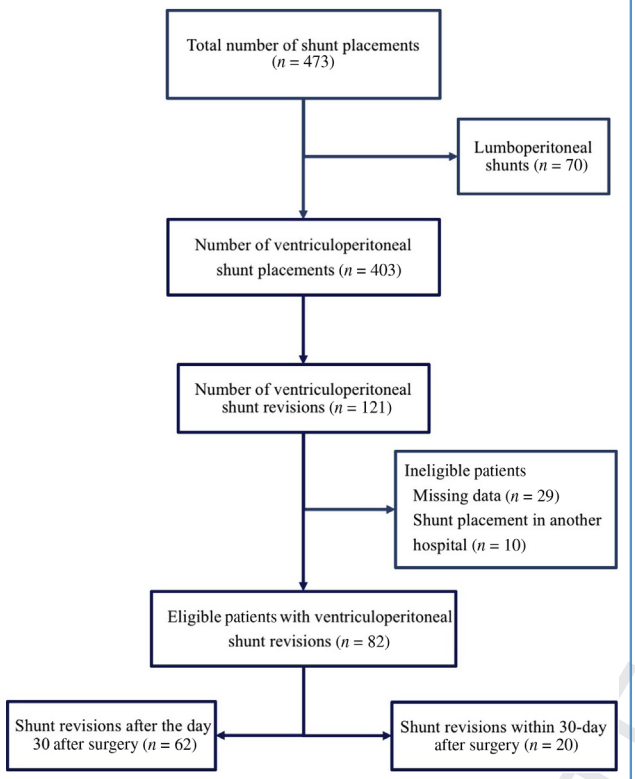

Figure 1. Flowchart showing how eligible patients were selected and enrolled in the study.

Forty-five percent of the patients in the early revision group were pediatric, whereas 71% of the patients in the late revision group were pediatric; this finding was statistically significant ($P = 0.05$).

A considerable percentage of patients in the early revision group were female (65%); however, males (65%) were more likely to have late revision ($P = 0.03$). Evaluation of household income in both groups showed that shunt revisions were more likely to happen in the middle group; the statistical analysis was not significant among the groups ($P = 0.77$).

Assessment of the underlying cause of hydrocephalus showed that, although the most common cause in the early revision group was brain hemorrhage (35%), and in the late revision group, congenital anomalies (45.8%), the statistical analysis did not show a significant difference ($P = 0.08$). Likewise, our results showed that failure of the proximal catheter is the main type of shunt failure in both early (70.0%) and late cases (56.4%), but no significant statistical difference was found. Similarly, there was no significant difference between both groups for some other factors including level of education, time of surgery, and duration of the operation. Comparison of the means for GCS between both groups was significant ($P = 0.04$) and mean values in early and late revision cases were 12.52 ± 3.83 and 13.90 ± 1.98, respectively.

Univariate analysis showed that gender, age, anatomic site of the catheter, GCS score, surgeons' level of expertise, and cause of hydrocephalus were significant factors (Tables 3 and 4).

Table 1. Demographic Characteristics of Eligible Patients

Variable	Frequency (%)
Gender	
Male	47 (57.3)
Female	35 (42.7)
Age	
Pediatric	53 (64.6)
Adult	29 (35.4)
Mean age ± standard deviation (years)	16.71± 19.84
Household income*	
Low	11 (13.4)
Middle	36 (43.9)
High	31 (37.8)
Level of education*	
Illiterate	24 (30.8)
Primary school	8 (10.2)
High-school diploma	42 (53.9)
University degree	4 (5.1)

*4.9% missing data.

Based on the criterion of $P < 0.1$ in the univariate analysis, 6 factors mentioned earlier were included in the logistic regression model. After adjustment, 2 factors (surgeons' level of expertise and anatomic site of the shunt) were associated with the occurrence of early shunt revision. The odds ratio for surgeons' level of expertise (junior resident) was 10.33 (95% confidence interval, 1.08–98.80) and for the anatomic site of the shunt (frontal vs. occipital), it was 10.28 (95% confidence interval, 1.21–87.35) (Table 5).

DISCUSSION

VPS is the mainstay management for hydrocephalus in both adult and pediatric patients; however, besides the benefits, some complications may arise and lead to shunt failure.[12] In this study, we aimed to retrospectively evaluate the rates and causes of 30-day shunt failure in patients with hydrocephalus in Ghaem Teaching Hospital, the only referral hospital in north-eastern Iran.

In the current study, the frequency of shunt revision was 30% among all patients receiving VPS, and after excluding ineligible cases, 24.4% of the patients had early revision surgeries (Figure 1). Generally, our results are consistent with those of Anderson et al.,[17] who evaluated the 30-day shunt failure rate over 5 years for both adult and pediatric patients. These investigators found that the 30-day shunt revision rate was 23.4% in pediatric patients and 25.6% in adult patients.

Previous studies have reported that the frequency of complications after VPS placement is between 20% and 40%.[15,18,19]

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Table 2. Clinical Factors of Eligible Patients

Variable	Frequency (%)
Cause of hydrocephalus*	
Congenital	30 (36.5)
Neoplasm	19 (23.1)
Brain hemorrhage	9 (10.9)
Spinal dysraphism	8 (9.7)
Postinfection	7 (8.5)
Normal pressure hydrocephalus	6 (7.3)
Anatomic site	
Occipital	75 (91.5)
Frontal	7 (8.5)
Surgeons' level of expertise	
Attending	45 (54.9)
Senior	29 (35.3)
Junior	8 (9.8)
Duration of operation (minutes)	
30	20 (24.4)
60	48 (58.5)
90	9 (11.0)
120	2 (2.4)
>120	3 (3.7)
Time of surgery	
Morning	13 (15.9)
Afternoon	17 (20.7)
Night	52 (63.4)
Mean Glasgow Coma Scale score ± standard deviation	13.58 ± 2.50
Time interval between insertion and revision	
Early	20 (24.4)
Late	62 (75.6)
Causes of revision†	
Obstruction	44 (53.6)
Malposition	11 (13.4)
Disconnection	10 (12.1)
Infection	4 (4.8)
Overdrainage	4 (4.8)
Type of failure	
Proximal	49 (59.7)
Distal	23 (28)
Complete revision	3 (3.6)
Valve change	2 (2.4)
Other	5 (6)

*4% missing data.
†11% missing data.

Causes of Shunt Revision

In our study, obstruction and malposition developed more frequently in both groups, and obstruction is the most common cause of shunt failure according to the literature.[20] In most studies, the proximal catheter is reported to be the most common site of obstruction.[21-23] One possible hypothesis is that the proximal catheter might become blocked with brain parenchyma and pieces of choroid plexus after shunt placement.[3] Another theory holds that catheters with nonprogrammable valve cannot regulate overdrainage, which cannot prevent sedimentation of debris in the proximal catheter.[21]

As mentioned earlier, malposition of the catheter, especially in the proximal part, is another cause of early revision. To obtain more precision and to avoid this problem, ultrasonographic assisted shunt placement might be a better substitute for the conventional methods of placement. For instance, Crowley et al.[24] showed that using intraoperative ultrasonography can increase the accuracy of shunt insertion in the proximal site, especially in patients with small ventricles, such as benign intracranial hypertension or slit ventricle syndrome. Similarly, the accurateness of the distal catheter placement can be improved via laparoscopic insertion, which may result in more prolonged shunt survival.[25-28]

Age and Gender

Our study showed that adult patients are more prone to have early shunt revision surgeries, whereas pediatric patients are more likely to have late revisions. This result may be explained by the fact that surgical interventions, such as VPS placement in elderly patients, are more associated with iatrogenic trauma because of the fragile and atrophic brain parenchyma. Another probable justification for the high rate of failure in adults might be the insult to the cells of the choroid plexus within the cerebral ventricles of elderly patients, which results in accumulation of cellular debris and subsequent shunt blockage.[12] Among all included cases of shunt revision, there was a slight predominance of male patients to female patients, which is in accordance with previous studies.[6,29] Although most patients were male, early shunt revisions occurred more among females.

Household Income and Level of Education

We hypothesized that less-educated patients with poor socioeconomic status might not be able to provide the appropriate care for shunt at home, which may lead to some unpredictable complications (e.g., disconnection, wound infection, and wound

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Table 3. Univariate Analysis of Demographic Characteristics of Early and Late Revision

Variable	Early, n (%)	Late, n (%)	*P* Value
Gender			
Male	7 (35.0)	40 (65.0)	0.03
Female	13 (65.0)	22 (35.0)	
Age			
Pediatric	9 (45.0)	44 (71.0)	0.05
Adult	11 (55.0)	18 (29.0)	
Household income			
Low	2 (10.5)	9 (15.2)	0.77
Middle	10 (52.6)	26 (44.1)	
High	7 (36.9)	24 (40.7)	
Level of education			
Illiterate	6 (31.6)	18 (30.5)	
Primary school	2 (10.5)	6 (10.2)	0.71
High-school diploma	11 (57.9)	31 (52.5)	
University degree	0 (0)	4 (6.8)	

*The between-group analysis was performed by χ^2 and Fisher exact test as appropriate.

Table 4. Univariate Analysis of Clinical Characteristics of Early and Late Revision Patients

Variable	Early, n (%)	Late, n (%)	*P* Value
Cause of hydrocephalus			
Congenital	3 (15.0)	27 (45.8)	
Neoplasm	5 (25.0)	4 (6.8)	
Brain hemorrhage	7 (35.0)	12 (20.3)	0.08
Spinal dysraphism	2 (10.0)	5 (8.5)	
Postinfection	2 (10.0)	6 (10.1)	
Normal pressure hydrocephalus	1 (5.0)	5 (8.5)	
Anatomic site			
Frontal	5 (25.0)	2 (3.2)	0.008
Occipital	15 (75.0)	60 (96.8)	
Surgeons' level of expertise			
Attending	6 (30.0)	39 (62.9)	0.001
Senior resident	8 (40.0)	21 (33.9)	
Junior resident	6 (30.0)	2 (3.2)	
Duration of operation (minutes)			
30	7 (35.0)	13 (21.0)	
60	11 (55.0)	37 (59.7)	
90	2 (10.0)	7 (11.3)	0.57
120	0 (0)	2 (3.2)	
>120	0 (0)	3 (4.8)	
Time of surgery			
Morning	4 (20.0)	9 (14.5)	
Afternoon	6 (30.0)	11 (17.7)	0.34
Night	10 (50.0)	42 (67.8)	
Mean Glasgow Coma Scale score ± standard deviation	12.52± 3.83	13.90± 1.98	0.04
Causes of revision			
Obstruction	10 (58.8)	34 (60.8)	
Malposition	4 (23.5)	10 (17.8)	0.32
Disconnection	0 (0)	7 (12.5)	
Infection	1 (5.9)	3 (5.3)	
Overdrainage	2 (11.8)	2 (3.6)	
Type of failure			
Proximal	14 (70.0)	35 (56.4)	
Distal	2 (10.0)	21 (33.9)	
Complete revision	2 (10.0)	1 (1.6)	0.1
Valve change	0 (0)	2 (3.3)	
Other	2 (10.0)	3 (4.8)	

*The between-group analysis was performed by χ^2, Fisher exact, and *t* test as appropriate.

dehiscence). Although in our study there was no significant association between these factors and early shunt revision, the probable social factors that might influence the risk of shunt complications have yet to be determined.

Cause of Hydrocephalus and Anatomic Site of the Shunt

In our study, there was no association between the cause of hydrocephalus and shunt failure rate, which might be attributable to the relatively small number of eligible patients in the current study. Similarly, the findings of Rossi et al.[14] showed that the cause of hydrocephalus is not associated with the risk of shunt revision. On the other hand, this finding is contrary to some previous studies, which have found that there is a significant association between the cause of hydrocephalus and shunt failure.[9,17,30-33]

Our results indicated that frontal placement of VPS is associated with a higher rate of shunt failure in both pediatric and adult cases. In our institution, the optimal choice for placement of a ventricular catheter is a posterior location to minimize cosmetic problems. However, there is some evidence to suggest that frontal placement of a catheter is associated with increased occurrence of shunt failure.[19,34] A possible explanation for this issue might be a difference in the levels of biomechanical stress on the shunt valve in frontal and occipital sites.[19] However, uncertainty exists over where the best target for ventricular catheter is located.[34]

Time of Surgery and Duration of Operation

In our study, most patients who underwent shunt surgery were placed on a nighttime schedule, but there was not a significant

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Table 5. Multivariate Analysis of the Demographic and Clinical Characteristics of the Patients with Early Shunt Revision

Clinical and Demographic Factors	*P* Value	Odds Ratio	Confidence Interval
Gender (Ref*: male)	0.11	3.32	0.75–14.71
Age (Ref: pediatric)	0.52	2.12	0.21–21.45
Anatomic site (Ref: occipital)	0.03	10.28	1.21–87.35
Glasgow Coma Scale	0.48	0.91	0.71–1.17
Cause of hydrocephalus			
Congenital (Ref)	0.89	—	—
Neoplasm	0.59	2.28	0.10–47.94
Brain hemorrhage	0.45	2.44	0.23–25.76
Spinal dysraphism	0.37	3.38	0.23–48.59
Postinfection	0.6	2.02	0.13–29.55
Normal pressure hydrocephalus	0.98	0.964	0.02–35.87
Surgeons' level of expertise			
Attending (Ref)	0.11	—	—
Senior resident	0.21	2.7	0.56–13.04
Junior resident	0.04	10.33	1.08–98.80

*Ref: Reference category.

association between time of surgery and the risk of early shunt revision. It may seem that surgeries carried out during the night were urgent cases and performed by a junior resident, and early complications are expected after shunt placement. However, because our institution is the main referral hospital in north-eastern Iran and many surgeries are carried out during daytime, limited theater access can lead to significant reductions in elective daytime operations and to shifting of some operations from daytime to nighttime. Hence, the proportion of shunt surgeries for less urgent cases performed by attending and seniors during nighttime was higher than that observed during daytime hours.

Our results also show that the duration of the operation was not a significant factor, whereas shunt placement lasting longer than average usually points to some difficulties during the procedure, which in turn could be associated with early complications. Although prolonged operative time could result in some difficulties and complications, factors contributing to the various associations between duration of surgery and complications are likely to be multifaceted and to differ. These factors can include preoperative (e.g., length of stay before operation), intraoperative (e.g., operating technique and average duration of surgery), and postoperative (e.g., postoperative length of stay) factors.[35] Understanding how all these additional risk factors can affect the association between operative time and complication risk warrants further investigation.

Surgeons' Level of Expertise and GCS

Our study reiterates the previously shown association between grading of surgeons and the rate of shunt revisions, such that patients operated on by junior residents were more likely to have early revision surgeries. Likewise, previous studies have shown that there is an association between the risk of shunt failure and surgeons' level of expertise.[36,37] Inversely, some studies have reported that there was no correlation between rates of shunt failure and surgeons' level of expertise.[19,38] Although there is no consensus on this issue, it seems that level of expertise should be considered as a potentially influential factor when evaluating a surgical procedure.

GCS is representative of preoperative clinical status, and it is a predictive parameter for shunt outcome, especially in traumatic brain injuries.[39]

Assessment of the GCS score showed a lower mean in the early revision group than in the late revision group. This finding is in agreement with data obtained by Khan et al.[12] indicating that patients with lower preoperative GCS score might be more susceptible to developing shunt failure.

Strengths and Limitations

Our neurosurgical center is the only referral hospital in north-eastern Iran; thus, we believe that our findings can shed light on the various dimensions of early shunt failure in north-eastern Iran.

One of the novelties in our study is the evaluation of 3 potential predisposing factors: household income, level of education, and time of surgery in the patients' medical history. Although there was no significant association among them, clarification of the impact of these factors on early shunt failure warrants further studies with greater sample size.

One of the shortcomings of our study is the retrospective design that is an inevitable limitation in cross-sectional studies. Also, some of the patients had come to our institute from different centers in neighboring provinces, which made it a challenge for us to have access to the details of their medical histories. Therefore, we had to exclude some patients because of the inaccuracy of the required medical information (**Figure 1**).

Another limitation is that we did not compare adult and pediatric patients for the occurrence of the main outcome separately, and it is conceivable that complications related to shunt placement might be different according to patients' age. However, because of the relatively low number of patients in the early revision group, if we divide the groups based on this factor, we do not have enough cases to perform an accurate statistical analysis of our data.

CONCLUSIONS

Our results highlight that surgeons' level of expertise and anatomic site of the shunt are associated with early shunt failure. Resident-performed surgeries have a higher failure rate than do attending-performed surgeries and shunts inserted through the frontal site are more prone to failure. Thus, it seems that close supervision of attendings is necessary to prevent early complications in VPS surgery.

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