Long-Term Outcomes of Ventriculoperitoneal Shunt Surgery in Patients with Hydrocephalus

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Key words
- Cerebrospinal fluid
- Communicating hydrocephalus
- Obstructive hydrocephalus
- Shunt complication
- Shunt failure
- Shunt revision

Abbreviations and Acronyms
CI: Confidence interval
CSF: Cerebrospinal fluid
NPH: Normal-pressure hydrocephalus
VP: Ventriculoperitoneal

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OBJECTIVE: **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 objective of this study is to review our long-term experience and evaluate the risk factors for VP shunt failure after initial shunt surgery and after subsequent revisions.**

METHODS: **Patients who underwent VP shunt surgery for hydrocephalus were included. Medical charts, operative reports, imaging studies, and clinical follow-up evaluations were reviewed and analyzed retrospectively.**

RESULTS: **A total of 1015 patients with the median age of 41.6 (range, 0—90.3) years at the time of VP shunt surgery were included. The mean and median follow up was 9.2 and 6.5 years, respectively. Adult patients (≥17 years) accounted for 70.0% of the patients. The overall shunt failure rate requiring shunt revision(s) was 46.3%, and the majority of shunt revisions occurred during the first 6 months after shunt placement. The shunt revision rate was significantly greater in pediatric (<17 years) than in adult (>17 years) patients (78.2% vs. 32.5%, $P < 0.001$). Age at the time of shunt surgery, previous treatments to shunt surgery, etiology of hydrocephalus, and hydrocephalus type were independently associated with the incidence of shunt revision. Age at shunt placement and sex were significantly associated with multiple shunt revisions. Among populations with at least one shunt revision, pediatric patients had significantly lower shunt survival rate and shorter median time to subsequent shunt revision than the adult (>17 years) patients; male patients had greater odds for multiple revisions than female patients.**

CONCLUSION: **The findings of the study indicate that age at shunt placement, etiology of hydrocephalus, type 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.**

INTRODUCTION

Shunting of the cerebrospinal fluid (CSF) from the ventricular system to the peritoneum remains the primary treatment option for patients with hydrocephalus and might also be a secondary treatment for those who do not improve after endoscopic third ventriculostomy (8, 15, 29). Although the diversion of CSF through shunting is the mainstay of hydrocephalus treatment, surgical complications cause a significant medical and social burden (3, 5, 16). Moreover, shunt complications commonly require multiple surgical procedures, as well as shunt revisions, during a patient's lifetime (19, 28, 30, 32). Shunt complications and revisions or failures can occur as the result of both proximal and distal causes (9) and account for a significant proportion of the morbidity associated with ventriculoperitoneal (VP) shunt surgery (4, 7, 16).

Despite the significant advances in shunt technology and treatment approaches in neurosurgery, many patients with hydrocephalus experience relatively high rates of shunt failure and must undergo a shunt revision or replacement. Previous studies have shown that the VP shunt surgery is effective with improved neurological outcomes in patients with hydrocephalus (2, 18, 33). Among various risk factors possibly related to shunt failure, patient demographics such as age, etiology of hydrocephalus, type of hydrocephalus, and other perioperative variables have received considerable attention, although conclusions have been drawn regarding their significance in the genesis of shunt failure (6).

Recently, we have shown that etiology of hydrocephalus, age, and sex significantly correlated independently with the incidence of infection in 1015 patients who underwent VP shunt surgery (21). In our earlier studies, we demonstrated that the etiology of hydrocephalus plays a significant role in shunt survival/revision in adult patients with hydrocephalus (23, 24).

Moreover, tumor histology was shown to be associated independently with shunt survival in patients with hydrocephalus and intracranial tumors (22). In this study, we report outcomes of a single institution's long-term experience with 1015 hydrocephalus patients treated with VP shunt surgery at the Louisiana State University Health Sciences Center-Shreveport.

MATERIALS AND METHODS

The details of identification of the patients, their selection, and criteria of inclusion and exclusion were reported previously (21). To summarize, using the database (MD Analyze, Medtech Global Ltd., South Melbourne, Victoria, Australia), we identified patients with hydrocephalus treated with VP shunt surgery at the Louisiana State University Health Sciences Center-Shreveport. Of these patients, only 80 (8 patients during 1960s, 20 during 1970s, and 52 during 1980s) were treated before 1990.The rest of the patients (n = 935) who were included in the study had VP shunt surgery between October 1990 and February 2010.

Medical charts, operative reports, imaging studies, and clinical follow-up evaluations were reviewed for all patients who underwent VP shunt surgery for hydrocephalus. The protocol for shunt surgery was determined by the guidelines recommended by the Center for Disease Control (13). Information on each patient, including age, sex, ethnicity, etiology of hydrocephalus, type of hydrocephalus, date of shunt placement, date of first shunt revision, number of shunt revisions, and shunt malfunction or failure were collected from patient records and analyzed.

The primary outcome of interest was the overall shunt revision rate and the risk factors associated with shunt failure. Shunt failure was defined as either revision or replacement after shunt insertion. The patient diagnoses were grouped into the following eight etiologies: congenital, idiopathic, tumors/cysts, cerebral hemorrhage, spinal dysraphism, postcraniotomy, posttraumatic, and "other." Aqueduct stenosis, meningitis, encephalocele, and sarcoidosis were included in the "other" category of etiology. Cerebral hemorrhage included the patients with subarachnoid hemorrhage, intracranial hemorrhage, subdural hemorrhage, and intraventricular hemorrhage.

Statistical Procedures

The χ^2 or Fisher test was used to compare groups on shunt failure rate. The Wilcoxon rank-sum test was used to compare groups that are significantly different on shunt failure rate on average number of shunt revisions or failures. Multiple logistic regression analysis was used to determine independent risk factors for shunt revision. The Kaplan-Meier method of survival analysis was used to estimate the shunt survival (revision-free) rate and to determine the incidence of shunt revision at 6 month, 1 year, 5 years, 10 years, and 20 years after shunt surgery. The log rank test was used to compare shunt survival rate between pediatric and adult patients. Probability values less than 0.05 were considered statistically significant.

RESULTS

Patient Demographics

The details of the patient demographics were described elsewhere (21). To summarize, the study included 1015 patients who underwent VP shunt surgery. The median age of the patients at the time of VP shunt placement was 41.6 (range, 0–90.3) years. Of the 1015 patients, 305 (30.0%) were pediatric patients (<17 years) and 710 (70.0%) were adults (≥17 years) at the time of shunt placement. The most common etiologies of hydrocephalus in the patient sample include tumors and cysts (24.1%), cerebral hemorrhage (19.9%), idiopathic (19.8%), congenital (10.3%) posttraumatic (6.9%), spinal dysraphism (6.4%), postcraniotomy (4.4%), and other (8.1%). Among types of hydrocephalus, obstructive hydrocephalus accounted for 51.3%, whereas communicating hydrocephalus and normal-pressure hydrocephalus (NPH) were present in 28.7% and 12.5% of the patients, respectively. The other hydrocephalus type represents 7.5% of the patient population. Of the 1015 patients, 172 (17.0%) had procedures before the VP shunt placement (Table 1). The mean and median follow-up time was 9.2 and 6.5 years, respectively, after the initial shunt surgery. Of the 1015 patients, 296 (286 adults and 10 pediatrics) were either lost to follow up or died.

Incidence of Shunt Revision

The findings presented in Table 2 reveal the rate of shunt revision in 1015 patients after shunt surgery for hydrocephalus. Of the 1015 patients who underwent shunt surgery, 470 (46.3%) experienced one or more shunt failures requiring shunt revision(s). Single shunt revision occurred in 205 (20.2 %) patients and multiple shunt revisions occurred in 265 (26.1%) patients after the initial shunt surgery. The shunt revision rate in pediatric patients was 78.7% (240 of 305 patients) and in adult patients was 32.4% (230 of 710 patients). The incidence of single shunt revision was 21.3% and 19.7% in pediatric and adult patients, respectively. The incidence of multiple shunt revision was 57.4% and 12.7% in pediatric and adult patients, respectively. Mean number of shunt revision in pediatric patients was 2.6 (range, 0–17) and 0.6 (range, 0–11) for adult patients.

Comparison of Shunt Revision Rate by Demographics, Etiology, and Type of Hydrocephalus

Univariate analysis indicated that the incidence of shunt revision differed significantly among categories of a number of demographic variables of the patients (Table 1). However, no significant differences were observed in shunt revision rate by sex ($P > 0.26$). White patients had significantly lower incidence of shunt revision compared with black patients (41.4% vs. 54.5%, $P < 0.01$). The incidence of shunt revision was significantly greater in pediatric (<17 years) patients than the adult (≥17 years) patients (78.2% vs. 32.5%, $P < 0.01$). Patients with previous shunt procedure experienced significantly greater shunt revision than those with no previous procedure (81.4% vs. 39.1%, $P < 0.01$). Etiology of hydrocephalus was significantly associated with shunt revision among hydrocephalus patients. Patients with congenital and spinal dysraphism experienced a significantly greater incidence of shunt revision (83.8% and 76.9%) followed by cerebral hemorrhage (61.9%), posttraumatic (48.6%), postcraniotomy (24.4%), tumors/cysts (33.5%), and idiopathic hydrocephalus (17.9%, $P < 0.01$). Notably, patients with other etiologies also experienced a greater incidence of shunt revision (53.7%). The shunt revision rate was significantly greater ($P < 0.01$) among patients with and other types of hydrocephalus (77.6%) followed by obstructive hydrocephalus (52.6%) and communicative