



## The Rate of Complications after Ventriculoperitoneal Shunt Surgery

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■ **BACKGROUND:** Although ventriculoperitoneal shunt (VPS) surgery is the most frequent surgical treatment for patients with hydrocephalus, modern rates of complications in adults are uncertain.

■ **METHODS:** We performed a retrospective cohort study of adult patients hospitalized at the time of their first recorded procedure code for VPS surgery between 2005 and 2012 at nonfederal acute care hospitals in California, Florida, and New York. We excluded patients who during the index hospitalization for VPS surgery had concomitant codes for VPS revision, central nervous system (CNS) infection, or died during the index hospitalization. Patients were followed for the primary outcome of a VPS complication, defined as the composite of CNS infection or VPS revision. Survival statistics were used to calculate the cumulative rate and incidence rate of VPS complications.

■ **RESULTS:** A total of 17,035 patients underwent VPS surgery. During a mean follow-up of 3.9 ( $\pm$  1.8) years, at least 1 VPS complication occurred in 23.8% (95% confidence interval [CI], 22.9%–24.7%) of patients. The cumulative rate of CNS infection was 6.1% (95% CI, 5.7%–6.5%) and of VPS revision 22.0% (95% CI, 21.1%–22.9%). Most complications occurred within the first year of hospitalization for VPS surgery. Complication rates were 21.3 (95% CI, 20.6–22.1) complications per 100 patients per year in the first year after VPS surgery, 5.7 (95% CI, 5.3–6.1) in the second year after VPS surgery, and 2.5 (95% CI, 2.1–3.0) in the fifth year after VPS surgery.

■ **CONCLUSIONS:** Complications are not infrequent after VPS surgery; however, most complications appear to be clustered in the first year after VPS insertion.

### INTRODUCTION

Ventriculoperitoneal shunt (VPS) insertion is the most frequently used surgical treatment for patients with hydrocephalus, with more than 30,000 procedures performed yearly in the United States.<sup>1</sup> VPS surgery was first reported in 1898<sup>2</sup> and since then has become the mainstay of treatment for hydrocephalus; however, complications including infection and shunt malfunction continue to occur, leading to many hospital readmissions and 50 million dollars of economic expenditure per year.<sup>1-3</sup>

Although VPS insertion is a common neurosurgical procedure, complication rates in adults are poorly established, with a reported range from 17% to 33%<sup>4-12</sup>; most of these data come from small case series, single-institution studies, or analyses from more than a decade ago. Given the recent advances in medical care, the aim of this study was to evaluate the rate of VPS complications in a large heterogeneous group of adult patients.

### METHODS

#### Study Design

To evaluate the rate of complications after VPS surgery, we used administrative claims data on all discharges from nonfederal emergency departments (EDs) and acute care hospitals in 3 large and demographically heterogeneous states: California, New York,

#### Key words

- Brain abscess
- Central nervous system infections
- Epidemiology
- Hydrocephalus
- Neurosurgery
- Ventriculoperitoneal shunts

#### Abbreviations and Acronyms

CI: Confidence interval

CNS: Central nervous system

ED: Emergency department

ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification

VPS: Ventriculoperitoneal shunt

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and Florida. Trained analysts at nonfederal EDs and acute care hospitals used standardized methods to collect data about discharges and transmitted these to retrospective state agencies. After quality checking, these data were reported in a deidentified format to the Agency for Healthcare Research and Quality for its Healthcare Cost and Utilization Project.<sup>13</sup> A unique record linkage number for each patient allowed longitudinal tracking of ED encounters and hospitalizations.<sup>14</sup> This study was approved by the Weill Cornell Medical College institutional review board.

### Study Patients

We identified all patients aged 18 years or older who were discharged from a nonfederal ED or acute care hospital in California from 2005 to 2011, Florida from 2005 to 2012, and New York from 2006 to 2011. These observational periods were chosen to ensure at least 1 year of follow-up data for all study patients. We included all patients at the time of their first recorded procedure code for VPS surgery as defined by previously validated International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code 02.34.<sup>15</sup> This code has a 95% sensitivity and 100% specificity based on medical record review.<sup>15</sup> We excluded patients who during the index hospitalization for VPS surgery had concomitant codes for VPS revision, had documented central nervous system (CNS) infection (bacterial meningitis or brain abscess), or did not survive the index hospitalization. These exclusionary criteria were used because our objective was to evaluate the long-term risk of complications in patients who received VPS surgery and were discharged alive without known complications during the initial hospitalization when a VPS was inserted. To maximize our ability to assess longitudinal follow-up, we excluded patients who did not permanently reside in California, New York, or Florida.

### Measurements

The primary outcome was the rate of VPS complications, defined as the composite of CNS infection and VPS revision. CNS infection was defined as meningitis or abscess using ICD-9-CM diagnosis codes (see [Supplemental Appendix](#)). A VPS revision or malfunction was defined using ICD-9-CM procedure and diagnosis codes as the presence of at least 1 of the following procedure codes: exploration of a ventricular shunt, replacement or revision of a ventricular shunt, removal of ventricular shunt, distal shunt revision, or shunt malfunction (see [Supplemental Appendix](#)). In a secondary analysis, we included nontraumatic subdural hematoma as another potential consequence of overdrainage from the VPS using ICD-9-CM code 432.1. Patients were censored at the time of their first complication, at death, or at the end of the follow-up period. We also evaluated predictors of VPS complications including demographic characteristics, insurance status, hospital volume of VPS surgery, and the baseline diagnosis for the VPS at the time of the initial VPS insertion. Because we lacked data on out-of-hospital mortality, all patients without a documented in-hospital death were assumed to have survived throughout the follow-up period for which we had data; however, we also performed a sensitivity analysis that accounted for out-of-hospital mortality by censoring patients at the time of their last ED visit or hospitalization.

### Statistical Analysis

Descriptive statistics with exact confidence intervals (CIs) were used to report crude rates. For univariate analyses, variables were compared using  $\chi^2$  statistics for categorical variables and the *t* test for continuous variables. Kaplan-Meier survival statistics were used to calculate the cumulative rate and incidence rate of VPS complications. Poisson regression with robust standard errors was used to evaluate factors associated with VPS complications and to adjust for demographic characteristics (age, sex, and insurance status). Statistical significance was defined using an  $\alpha$  of 0.05. All analyses were performed with Stata/MP version 13 (College Station, Texas, USA).

## RESULTS

### VPS Complications

We identified 17,035 patients who underwent VPS surgery. The most common baseline diagnoses in patients requiring VPS were communicating hydrocephalus, idiopathic normal pressure hydrocephalus, and obstructive hydrocephalus; these accounted for 64% of cases ([Table 1](#)). During a mean follow-up of 3.9 ( $\pm 1.8$ ) years, at least 1 VPS complication occurred in 23.8% (95% CI, 22.9%–24.7%) of patients. The cumulative rate of CNS infection was 6.1% (95% CI, 5.7%–6.5%) and that of VPS revision was 22.0% (95% CI, 21.1%–22.9%). When nontraumatic subdural hematoma was included, the cumulative rate of any complication throughout follow-up was 33.4% (32.4%–34.4%). The cumulative rate of nontraumatic subdural hematoma was 14.4% (95% CI, 13.5%–15.3%). Hospitalization with a VPS complication was associated with a 2.7% mortality.

Most complications occurred within the first year of the initial VPS insertion ([Figure 1](#)). Complication rates were 21.3 (95% CI, 20.6–22.1) complications per 100 patients per year in the first year after VPS surgery, 5.7 (95% CI, 5.3–6.1) in the second year after VPS surgery, and 2.5 (95% CI, 2.1–3.0) in the fifth year after VPS surgery. Similar trends were seen when infection and VPS revision were assessed separately.

### Predictors of VPS Complications

In a multivariable analysis, we found no association between sex, race, or hospital volume of VPS surgeries with VPS complications. On the other hand, younger age was associated with a higher rate of VPS complications (incidence rate ratio per decade, 0.83; 95% CI, 0.81–0.86). Complications were more likely in those with benign intracranial hypertension, idiopathic normal pressure hydrocephalus, obstructive hydrocephalus, and communicating hydrocephalus ([Table 2](#)). In a sensitivity analysis that censored patients at the time of the last follow-up, our results were unchanged save for a new association between an underlying diagnosis of a brain tumor (compared with other hydrocephalus diagnoses) and the development of a VPS complication (incidence rate ratio, 2.84; 95% CI, 1.78–4.53).

## DISCUSSION

In a large, heterogeneous, population-based sample of patients who underwent VPS surgery, we found that the contemporary rate of VPS complications was 22.6% during a mean follow-up of 3.8

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