Rate and Risk Factors for Shunt Revision in Pediatric Patients with Hydrocephalus—A Population-Based Study

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■ BACKGROUND: **Ventriculoperitoneal shunt (VPS) is a common treatment for patients with hydrocephalus (HC). VPS is associated with complications that may lead to shunt revisions. We studied the surgical outcome of pediatric patients with HC in a population-based setting.**

■ METHODS: **The medical charts and imaging findings of 80 patients ≤16 years old who required VPS secondary to HC were studied.**

■ RESULTS: **Mean age at time of initial shunt placement was 3.2 years (SD 4.5) and mean follow-up time was 3.3 years (SD 2.9); 57% of patients were male. Half of patients underwent shunt revision with mean time to first revision of 8 months. Patients ≤6 months old had a higher shunt revision rate compared with patients >6 months old ($P < 0.001$). The most common causes of HC requiring VPS were tumors (27.5%), congenital defects (22.5%), and intraventricular hemorrhage (19%). Revision rates in the intraventricular hemorrhage and congenital defects groups were 67% ($P = 0.017$) and 72% ($P = 0.016$) compared with 32% in the tumor group. Programmable valves (56%) were more common than nonprogrammable valves, but there was no significant difference in shunt survival ($P = 0.632$). The mean biparietal measurement change between preoperative and postoperative images was +0.9 mm in the no revision group and +6.6 mm in the revision group ($P = 0.003$).**

■ CONCLUSIONS: **Half of patients with shunts required revision. Age ≤6 months and intraventricular hemorrhage and congenital defects etiologies of HC were associated with increased risk for shunt revision. Most revisions were done during the first year after the initial VPS.**

INTRODUCTION

Hydrocephalus (HC) is defined as an active expansion of the cerebrospinal fluid (CSF) space of the brain as a result of disturbance of CSF flow from its production site to its absorption site.[1] Prevalence varies from 0.4/1000 to 3.2/1000 according to the literature.[2-6] The 3 most common causes of HC are tumors, intraventricular hemorrhage (IVH), and congenital defects (CD).[7-10] Previous studies have shown that maternal risk factors for congenital HC include diabetes, multiple pregnancies, and use of antidepressants.[11,12] In addition, maternal hypertension is associated with fetal IVH-induced HC.[12] Infantile risk factors include male sex, familial history, and prematurity.[6,11,12]

Ventriculoperitoneal shunt (VPS) is the most common procedure to treat CSF circulation disturbances in children and adults.[13,14] VPS is associated with complications such as mechanical malfunctions (obstruction of valve or catheter, catheter disconnection or migration), overdrainage, and infection.[7,15-17] According to the literature, factors such as ethnicity, etiology of HC, prematurity, age <1 year, male sex, IVH, spina bifida, epilepsy, and degree of ventricular dilation can increase the risk of shunt revision in patients with HC.[10,18-21]

The published series on the outcome of pediatric patients with HC had short follow-up times[22] or used administrative

Key words
- Hydrocephalus
- Pediatric
- Population-based
- Revisions
- Shunting

Abbreviations and Acronyms
CD: Congenital defects
CSF: Cerebrospinal fluid
EVD: Extraventricular drain
HC: Hydrocephalus
IVH: Intraventricular hemorrhage
KUH: Kuopio University Hospital
MRI: Magnetic resonance imaging
VPS: Ventriculoperitoneal shunt

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databases,[8,20,23,24] where there was an inherent problem of selection bias and uncontrollable factors that can influence the outcome. Case series are vulnerable to selection bias, as the series are drawn from a particular population (e.g., clinic or hospital), and this may not reflect proportions in the wider population. We have collected a registry of all cases of pediatric HC from a defined population with full follow-up. In Finland, we have limited data on pediatric shunt surgical outcomes; therefore, we studied the outcome of pediatric patients with HC who required CSF shunts.

MATERIALS AND METHODS

Study Population

The Department of Neurosurgery at Kuopio University Hospital (KUH) solely provides full-time acute and elective neurosurgical services for the Eastern and Central Finnish catchment population. Since 1977, KUH has been the only neurosurgical referral center for Eastern and Central Finland (catchment population of 900,000 inhabitants) serving a defined, stable population. The KUH area contains 4 central hospitals with pediatric and neurologic units as secondary referral centers, and all pediatric patients with HC and shunts are referred to KUH. The present study was a population-based retrospective study of all pediatric patients undergoing their first insertion of a CSF shunt for treatment of HC. All patients from the KUH catchment area requiring CSF diversion for HC between January 1, 2003, and December 31, 2013, were included. Included patients were <16 years old at the time of initial shunt placement. The KUH ethics committee approved this study.

Clinical and Surgical Variables

The following variables were used in the analyses for all pediatric patients with HC: 1) patient-related variables, including sex, age at initial shunt placement, birth weight, and possible infections; 2) HC etiologies, including arachnoid cyst, aqueductal stenosis, CD, nonspecified HC, infection, intracerebral hemorrhage, IVH, stenosis of sigmoid sinus—jugular vein complex, trauma, and tumor; 3) variables related to CSF diversion, including extraventricular drain (EVD) or Rickham capsule insertion, performing surgeon, site of ventricle catheter placement, and initial valve type; and 4) variables related to surgical outcome, including time to first revision and causes of revisions.

Follow-Up

Follow-up of all patients was conducted in the Department of Neurosurgery at KUH. If shunt malfunction was suspected, appropriate imaging studies were performed at KUH or at central hospitals of the catchment area of KUH, and subsequent care was carried out solely at KUH.

Imaging Variables

Predetermined variables from preoperative and postoperative imaging were lateral ventricle width at caudate nucleus level, combined lateral ventricle corpus width compared with width of parenchyma from axial plane, third ventricle width in axial and coronal plane at foramen of Monro level, fourth ventricle anteroposterior measurement and width from axial plane, biparietal measurement from coronal plane, and the Evans index. These measurements were reviewed with a neuroradiologist. Only cases in which either preoperative or postoperative (or both) images were performed with magnetic resonance imaging (MRI) were included. Patients with serious CD or poor imaging were excluded ($n = 25$) because of anatomic reasons or insufficient imaging data.

Literature Review

A PubMed search was conducted from January 2000 to December 2016 using the following key words: "pediatric," "hydrocephalus," "shunt," and "revision." Nonhuman and non—English language studies were excluded as well as studies that did not have full-text version available. Abstracts were screened for studies that analyzed shunt survival. There were 9 full-text articles evaluated, from which only 2 relevant cohorts were found. **Figure 1** is a flow chart showing exclusion criteria, and the relevant cohorts are summarized in **Table 1**.

Statistical Analyses

Continuous variables were reported as means with SDs, and dichotomous and categorical variables were reported using frequencies and percentages. Pearson χ^2 for discrete variables and independent samples t test for continuous variables were used for group comparisons between patients stratified by shunt revision. A multivariate logistic regression analysis was used to identify the factors with an independent impact on shunt survival. The Kaplan-Meier method was used to estimate the time to shunt failure, and the log-rank test was used to compare the mean time to shunt failure or revision in patients with different etiologies of HC. IBM SPSS Statistics for Windows Version 21.0 (IBM Corp., Armonk, New York, USA) was used to carry out the analyses. Differences were statistically significant if the P value was <0.05.

RESULTS

Patient Characteristics

During the study period from 2003 to 2013, 80 primary pediatric CSF shunt operations were performed at KUH (**Table 2**). There were slightly more male patients (57%) than female patients (43%). Of patients, 37 were <6 months old. Weight of 41 patients (51%) was recorded at the time of the primary shunt

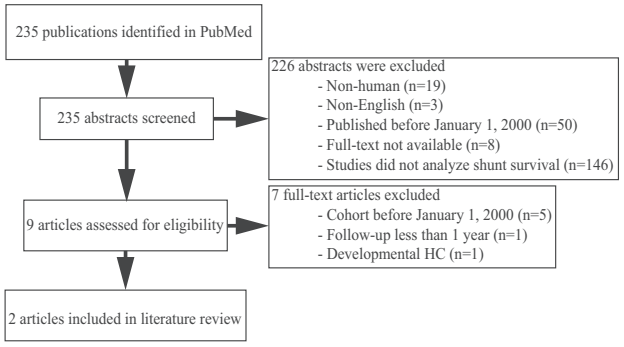

Figure 1. Flow chart of literature search and the selection of relevant clinical studies.