



Variability in Management of First Cerebrospinal Fluid Shunt Infection: A Prospective Multi-Institutional Observational Cohort Study

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Objectives To describe the variation in approaches to surgical and antibiotic treatment for first cerebrospinal fluid (CSF) shunt infection and adherence to Infectious Diseases Society of America (IDSA) guidelines.

Study design We conducted a prospective cohort study of children undergoing treatment for first CSF infection at 7 Hydrocephalus Clinical Research Network hospitals from April 2008 through December 2012. Univariate analyses were performed to describe the study population.

Results A total of 151 children underwent treatment for first CSF shunt-related infection. Most children had undergone initial CSF shunt placement before the age of 6 months (n = 98, 65%). Median time to infection after shunt surgery was 28 days (IQR 15-52 days). Surgical management was most often shunt removal with interim external ventricular drain placement, followed by new shunt insertion (n = 122, 81%). Median time from first negative CSF culture to final surgical procedure was 14 days (IQR 10-21 days). Median duration of intravenous (IV) antibiotic use duration was 19 days (IQR 12-28 days). For 84 infections addressed by IDSA guidelines, 7 (8%) met guidelines and 61 (73%) had longer duration of IV antibiotic use than recommended.

Conclusions Surgical treatment for infection frequently adheres to IDSA guidelines of shunt removal with external ventricular drain placement followed by new shunt insertion. However, duration of IV antibiotic use in CSF shunt infection treatment was consistently longer than recommended by the 2004 IDSA guidelines. (*J Pediatr* 2016;179:185-91).

Although life-saving and the mainstay of hydrocephalus treatment,¹ cerebrospinal fluid (CSF) shunts can cause new and chronic surgical and medical problems for children with hydrocephalus. Mechanical malfunction is frequent with 40% of shunts requiring surgical revision within 2 years.² With every surgery, the risk of CSF shunt infection increases.³⁻⁵ CSF shunt infection rates range from 0% to 35% per surgery.^{3,6-16} CSF shunt re-infection is frequent and rates range from 12% to 26%.^{4,17,18}

Even though numerous review articles have been published,^{1,19-22} no organization in the US or elsewhere has published an official guideline for management of CSF shunt infection. Instead, embedded within 2004 guidelines for management of bacterial meningitis, the Infectious Disease Society of America (IDSA) provided guidelines for both surgical and antibiotic decisions in the treatment of CSF shunt infection.²³

Surgical decisions in the treatment of CSF shunt infection include either shunt removal with external ventricular drain (EVD) placement followed by new shunt insertion, or shunt externalization followed by shunt replacement, after the CSF

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CSF	Cerebrospinal fluid
EVD	External ventricular drain
HCRN	Hydrocephalus Clinical Research Network
IDSA	Infectious Diseases of America
IV	Intravenous

is sterile. Although the benefit of each approach in preventing CSF shunt re-infection remains unclear,^{18-22,24-26} the growing consensus within the neurosurgical community has been to remove the shunt at the time of the first infection surgery.^{17,27} The 2004 IDSA guidelines reflect this growing consensus, suggesting shunt removal with EVD placement followed by new shunt insertion with an A-II ranking of evidence (ie, good evidence from ≥ 1 well-designed clinical trial[s] without randomization, from cohort or case-controlled studies, etc).²³

Antibiotic decisions in the treatment of CSF shunt infection include the choice and duration of empiric and targeted intravenous (IV) antibiotics.²⁸⁻³⁰ Here again, evidence is limited as no randomized controlled clinical trial has been conducted; prior studies have been retrospective and limited in size.²² The 2004 IDSA guidelines for duration of IV antibiotics were provided with a B-II ranking of evidence (ie, moderate evidence from ≥ 1 well-designed clinical trial[s] without randomization, from cohort or case-controlled studies, etc).²³ Reported duration of IV antibiotic use varies widely, ranging from 4 to 47 days in one study,¹⁷ and depends, in part, on the surgical approach used,^{4,31} pathogen involved,^{23,30,32} and persistence of the pathogen.

Identification of optimal surgical and antibiotic treatment for CSF shunt infections has the potential to improve outcomes, but before a prospective interventional trial can be designed, current practices need to be better understood. The Hydrocephalus Clinical Research Network (HCRN) provides a unique opportunity to understand current practices for treatment of CSF shunt infection following creation of the IDSA guidelines. We aimed to describe the variation in approaches to surgical and antibiotic treatment for first CSF shunt infection, and rate of adherence to IDSA guidelines for CSF shunt infection treatment, in a prospective cohort of children with CSF shunt placement.

Methods

The HCRN is a collaboration of 9 pediatric neurosurgical centers across North America, with 7 participating in this study: Children's Hospital of Alabama, Children's Hospital of Pittsburgh, Hospital for Sick Children, Primary Children's Medical Center, Seattle Children's Hospital, Texas Children's Hospital, and St. Louis Children's Hospital. HCRN registry data use was approved by the HCRN and the Institutional Review Boards at the University of Utah and Seattle Children's Hospital.

Within the HCRN registry, data from each neurosurgical admission for each child admitted is collected contemporaneously. Data collection began in April 2008 and, for this study, ended on December 31, 2012, except for children at the Hospital for Sick Children who were followed until December 31, 2011. The final cohort included children whose initial CSF shunt placement, interval CSF shunt revision(s), and first CSF shunt infection were recorded in the HCRN registry during the study period.

The HCRN consensus definition was used for first CSF shunt infection:³³⁻³⁵ (1) microbiological determination of bacteria present in a culture or Gram stain of CSF, wound swab, and/

or pseudocyst fluid; or (2) shunt erosion (visible hardware); or (3) abdominal pseudocyst (without positive culture); or (4) for children with ventriculoatrial shunts, presence of bacteria in a blood culture. The first CSF sample for diagnosis of infection usually was obtained from needle aspiration of the shunt reservoir under sterile conditions and before initiation of antibiotic therapy. To ensure that all infections were identified, all neurosurgical admissions involving 2 CSF shunt surgeries and ≥ 48 hours of IV antibiotic treatment were reviewed by one author and local HCRN staff to confirm that infection criteria were not met.

Baseline characteristics considered included patient risk factors such as demographics, factors present prior to and at the time of initial CSF shunt placement, as well as intervening revision surgeries, as previously described and shown in **Table I**.^{34,36} Complex chronic conditions were classified as described previously.³⁷ Of note, hospitals within the HCRN have instituted an infection prevention bundle used at the time of initial shunt placement and at revision(s), although adherence to all aspects is variable^{33,38} (**Table II**; available at www.jpeds.com).

Factors considered during the treatment of first CSF shunt infection included chronologic age, complications after first shunt infection, and distal shunt location. Duration of time between infection surgeries was created to denote the timespan between the first and final surgical approaches to infection treatment. Next, we examined diagnostic and microbiological factors in CSF shunt infection.³⁵ We considered the specific infection criterion met; organism(s) recovered in CSF, blood, and wound culture(s); presence of bacteremia (defined as any organism recovered in blood culture, except for children with ventriculoatrial shunts diagnosed by blood culture); and, if available within 48 hours of infection diagnosis, results of the first CSF studies including Gram stain, white and red blood cell counts, glucose, and protein concentrations.

Among the CSF shunt infections diagnosed by CSF culture, we examined additional diagnostic and microbiological factors, including³⁵ duration of time from first positive culture to first infection surgery, duration of time from first persistently negative culture to final surgical procedure following infection, duration of positive CSF cultures, the presence of intermittent negative CSF cultures (defined as 2 or more positive CSF cultures with the same organism and at least 1 intervening negative culture), presence of secondary ventriculitis (recovery of a different organism from that recovered initially in CSF culture), and polymicrobial infection (defined as growth of more than one organism, including the same species, on the first culture from one source).

Surgical Management

The key surgical outcome variable was the surgical approach to treatment for CSF shunt infection.³⁹ Surgical approach was defined as: (1) full shunt removal with interim EVD placement followed by new shunt insertion once the CSF is sterile; (2) distal shunt externalization followed by shunt replacement; (3) distal shunt externalization followed by EVD placement followed by new shunt insertion (failed externalization);

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