

Management of shunt infections: a multicenter pilot study

JOHN R. W. KESTLE, M.D., HUGH J. L. GARTON, M.D., WILLIAM E. WHITEHEAD, M.D.,
JAMES M. DRAKE, M.D., ABHAYA V. KULKARNI, M.D., D. DOUGLAS COCHRANE, M.D.,
CHERYL MUSZYNSKI, M.D., AND MARION L. WALKER, M.D.

Department of Neurosurgery, Primary Children's Medical Center, University of Utah, Salt Lake City, Utah; Section of Neurosurgery, Department of Surgery, University of Michigan, Ann Arbor, Michigan; Department of Neurosurgery, Indiana University School of Medicine, Indianapolis, Indiana; Department of Neurosurgery, Children's Hospital of Wisconsin, Milwaukee, Wisconsin; Division of Neurosurgery, Hospital for Sick Children, University of Toronto, Ontario; and Children's and Women's Health Center of British Columbia, University of British Columbia, Vancouver, British Columbia, Canada

Object. Approximately 10% of cerebrospinal fluid (CSF) shunt operations are associated with infection and require removal or externalization of the shunt, in-hospital treatment with antibiotic agents, and insertion of a new shunt. In a previous survey, the authors identified substantial variation in the duration of antibiotic therapy as well as the duration of hospital stay. The present multicenter pilot study was undertaken to evaluate current strategies in the treatment of shunt infection.

Methods. Patients were enrolled in the study if they had a successful treatment of a CSF shunt infection proved by culture of a CSF specimen. Details of their care and the incidence of culture-proved reinfection were recorded.

Seventy patients from 10 centers were followed up for 1 year after their CSF shunt infection. The initial management of the infection was shunt externalization in 17 patients, shunt removal and external ventricular drain insertion in 50, and antibiotic treatment alone in three. Reinfection occurred in 18 patients (26%). Twelve of the 18 reinfections were caused by the same organism and six were due to new organisms. The treatment time varied from 4 to 47 days, with a mean of 17.4 days for those who later experienced a reinfection compared with 16.2 days for those who did not. The most common organism (*Staphylococcus epidermidis*, 34 patients) was associated with a reinfection rate of 29% and a mean treatment time of 12.8 days for those who suffered reinfection and 12.5 days for those who did not.

Conclusions. Reinfection after treatment of a CSF shunt infection is alarmingly common. According to the data available, the incidence of reinfection does not appear to be related to the duration of antibiotic therapy.

KEY WORDS • infection • ventriculoperitoneal shunt • treatment evaluation • pediatric neurosurgery

CEREBROSPINAL fluid shunt implantations account for a significant number of neurosurgical admissions and procedures.⁷ Although they have resulted in dramatic improvements in patient survival and neurological function, CSF shunts are associated with several complications. One of the most common is infection, which occurs in nearly 10% of patients.^{1,4,5} The treatment of shunt infection usually requires removal or externalization of the shunt and treatment with antibiotic agents for a period of time, followed by insertion of a new shunt.^{2,3}

The optimal duration of antibiotic therapy for infected shunts is not obvious from findings presented in the literature. From a review of anecdotal accounts, uncontrolled studies, and discussions with colleagues, it has become apparent that some surgeons treat CSF shunt infections for differing time periods. A similar variation in treatment duration was identified in the responses to a case-scenario questionnaire sent to members of the American Society of

Pediatric Neurosurgeons.⁸ To investigate the differences in treatment time further, we performed a pilot study for the following reasons: 1) to obtain detailed information on current methods of practice, and 2) to determine the incidence of recurrent shunt infection after treatment and the risk factors for recurrence.

Clinical Material and Methods

Patient Selection

We conducted a prospective multicenter observational study. The centers that were included in this study were children's hospitals that offer care provided by pediatric neurosurgeons. Patients presenting with symptoms of a shunt-related problem were examined according to the surgeon's usual clinical practice. If there was sufficient clinical suspicion of shunt infection, fluid was aspirated from the shunt, wound, or abdomen as indicated (that is, a "tap" was performed, and the fluid was sent for microbiological examination). In patients with ventriculoatrial shunts, blood cultures were examined as well.

Abbreviations used in this paper: CSF = cerebrospinal fluid; EVD = external ventricular drain.

Although the characterization of “sufficient clinical suspicion” was left up to the individual surgeon, the following scenarios usually led surgeons to perform a tap: fever associated with symptoms or signs of shunt obstruction, unexplained fever after a recent shunt operation, meningismus, wound erythema, purulent discharge from the wound, erosion of the shunt equipment through the wound or skin, abdominal pseudocyst, or peritonitis.

When the clinical evidence was insufficient to be indicative of one of the aforementioned conditions and the patient underwent a shunt revision, CSF was sent for Gram staining and culture at the time of surgery. In addition, some surgeons performed a tap as a routine part of the shunt evaluation, even in the absence of any of these factors. In either of these situations the results of the fluid examination were used to determine eligibility for the study. The surgeon’s reason for performing a tap was recorded.

Patients who met the following criteria were eligible for the study. 1) A CSF shunt infection was present. A CSF shunt was defined as a device implanted to divert CSF from the ventricles or from an intracranial cyst to the peritoneum or the heart. A CSF shunt infection was defined as the identification of organisms on a Gram stain or culture of CSF obtained from the shunt lumen, purulent material from around the shunt, abdominal fluid collection if present, or blood (in patients with ventriculoatrial shunts). Growth of organisms that appeared around the entire shunt material while cultured in broth was not considered an infection in the absence of other positive culture results. 2) Patients were younger than 19 years of age. 3) Patients had to be able to participate in the planned follow-up studies. 4) The expected patient survival was longer than 12 months. 5) Patients and their families were willing to give informed consent. Patients who received antibiotic agents prior to undergoing a tap (which may have occurred when patients were referred from outside institutions) were assessed according to the aforementioned criteria and were still eligible to participate in the study if the CSF culture was positive or organisms were identified on a Gram stain.

Patient Population

Seventy patients were enrolled from 10 centers between May 2001 and June 2004. The mean patient age was 5.4 years (range 26 days–18 years); approximately one quarter (23%) of the patients were younger than 1 year of age at the time infection was diagnosed. The proportions of male and female patients were equal. The most common causes of hydrocephalus were intraventricular hemorrhage in 21 patients, congenital hydrocephalus in 13, and myelomeningocele in 10. At the time of enrollment in the study, none of the patients was on a regimen of immunosuppressive therapy. Most patients (55) had a single ventriculoperitoneal shunt in place, and most (59) had distal drainage to the peritoneal space. Four shunts were atrial and one was pleural. All patients were observed for 1 year or until they experienced infection recurrence. Infection recurred in 18 (26%) of 70 patients. In 12 patients these reinfections were caused by the same organism as the original infection, and in six they were due to a different organism.

Case Management

The participating surgeons continued their usual methods

of shunt infection treatment; the details were recorded but not restricted. In general, management consisted of the following. Broad-spectrum antibiotic therapy commenced after the tap was performed but before the results of the tap were available. The choice of antibiotic agent was left to the participating surgeon. Within 48 hours of diagnosis of shunt infection one of the following strategies was followed. 1) The shunt was removed and an EVD was inserted. 2) The lower end of the shunt was externalized via an incision along the course of the shunt. 3) A decision was made to treat the infection without removing the shunt equipment. Antibiotic therapy was adjusted based on the results of the Gram staining and culture and sensitivity reports when they became available. Other interventions, such as replacing the EVD or administering intraventricular antibiotic agents, were recorded but not restricted. Specimens of CSF were collected daily and sent for cell count and culture. A new shunt was implanted when the treating surgeon thought it was appropriate (that is, according to the surgeon’s usual practice). The antibiotic regimen following shunt insertion was also dictated by the surgeon’s usual practice. At follow-up visits, the indications for performing a shunt tap and the definition of shunt infection were the same as those used in assessing eligibility (see earlier). Investigators at each center obtained local institutional review board approval, and the data were collated and analyzed at the University of Utah.

Results

Infection Characteristics

The reason for obtaining a CSF culture was “suspicion of infection” in 57 patients. Six infections were diagnosed at the time of CSF sampling, during what was thought to be a shunt malfunction unrelated to an infection. The last procedure performed prior to diagnosis of infection was a shunt insertion in 27 patients and a shunt revision in 39 patients. The last procedure was performed less than 6 months before diagnosis of infection in 60 of the 70 patients.

A history of shunt revisions was common in this population. Twenty-seven patients had not undergone a shunt revision, whereas 17 patients had fewer than five previous revisions and the remainder of the patients had five or more. Thirteen of the 70 patients had a history of shunt infection. Seven of the 13 had experienced shunt infection within the preceding 6 months, and that group had a recurrence rate of 43% after treatment of the current shunt infection. The six patients who suffered an infection more than 6 months previously had a 24% recurrence rate after treatment of the current shunt infection.

The most common organism was *Staphylococcus epidermidis*, which caused the infection in 34 patients; nine patients were infected by *Staphylococcus aureus*. The other organisms recorded were *Propionibacterium acnes*, *Streptococcus pneumoniae*, *Streptococcus viridans*, *Escherichia coli*, *Klebsiella* sp., and mixed flora.

Infection Treatment

The initial treatment of the infection was, most commonly, complete removal of the shunt and insertion of an EVD, which was done in 50 of the 70 patients. In 17 patients, the upper portion of the shunt system was left in situ and the

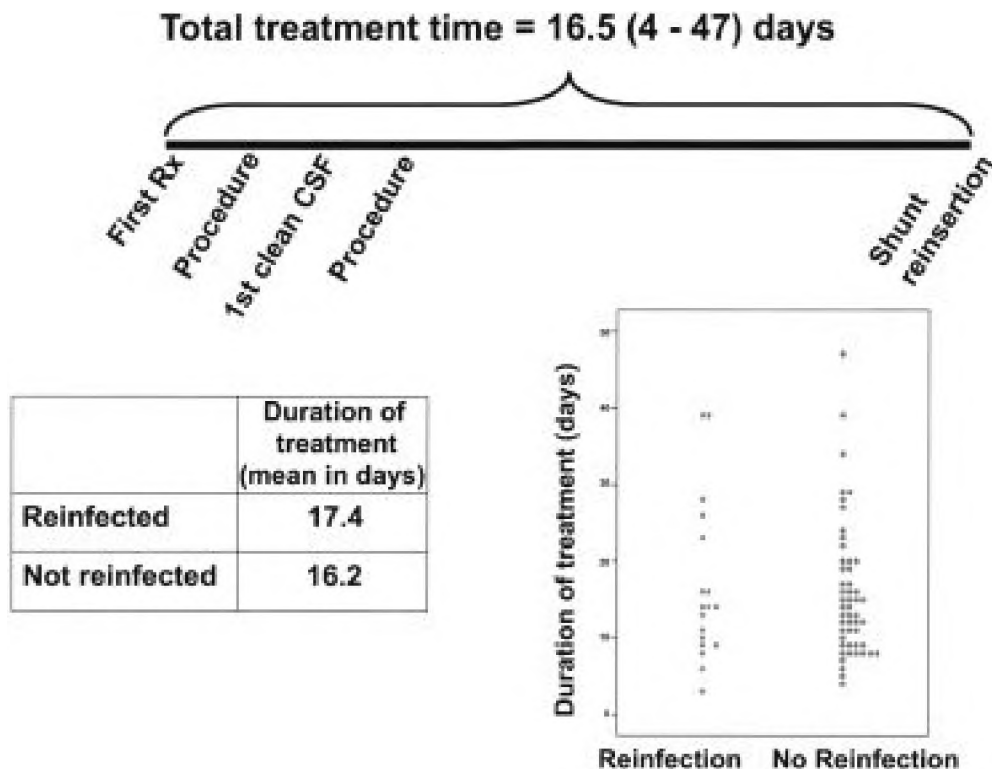


FIG. 1. Time line and charts showing the total treatment time and the incidence of reinfection. Clean CSF refers to CSF that is free of infection. Rx = treatment.

distal tubing was externalized through an incision along the shunt track. Three patients were treated without removal of any shunt equipment, and given antibiotic therapy alone. In one of them there was a slight growth of *Staphylococcus epidermidis* in the CSF of one specimen after 4 days of culture. This was interpreted as a possible contaminant; it was treated with antibiotic therapy alone and resulted in a recurrent infection. The second patient was found to have *Streptococcus pyogenes* in the blood. The distal portion of the shunt was in the atrium. This patient was treated with antibiotic agents alone, without a recurrence. In the third patient a growth of *Staphylococcus aureus* came from a wound infection. This infection was treated only with antibiotic medication, and the patient did not suffer a recurrence.

After the original surgical treatment of the shunt infection, 39 patients underwent additional procedures in which an EVD was exchanged or placed. Twenty-nine of the 39 patients underwent a single procedure and 10 underwent multiple external ventricular drainage procedures. At the time of shunt placement, a new entry site was made in 35 patients, and eight (23%) of these experienced a reinfection. In 28 patients, the same entry site was used for shunt insertion, and eight (29%) of these patients suffered a reinfection.

Treatment Time

The total treatment time from diagnosis to shunt reinsertion is depicted in Fig. 1. It ranged from 4 to 47 days (mean 16.5 days). The mean total treatment time for patients in whom reinfection developed was 17.4 days, and for those who did not experience reinfection it was 16.2 days.

After the CSF was found to be free of infection, treat-

ment continued from 3 to 46 days (mean 13 days; Fig. 2). For patients in whom a reinfection occurred, the mean duration of treatment was 14 days after the CSF was found to be infection free and for patients who did not experience a reinfection it was 12.7 days. When the patients are divided into groups based on the length of treatment after the CSF was noted to be free of infection, the reinfection rate for those treated for 7 days or less was 20% (four of 20 patients), and the rate for those treated for longer than 7 days was 28% (13 of 46 patients).

Twenty-two patients completed their treatment course without any intervening procedures to change the EVD after the original surgical treatment. The mean total treatment time was 11 days (range 3–23 days). Patients in this group in whom a reinfection developed had been treated for a mean of 10.5 days, whereas patients who did not experience a reinfection were treated for a mean of 11.8 days. When the same group was analyzed according to treatment time after their CSF was found to be infection free, the mean treatment time was 9 days (range 3–17 days) for those who experienced a reinfection and 9.1 for those who did not.

Among the 34 patients whose infection was due to *Staphylococcus epidermidis*, reinfection occurred in 10 (29%). The mean time to rid the CSF of infection was 2.7 days, and the mean total treatment time was 12.6 days (range 3–39 days). The mean treatment time after the CSF was infection free was 10.1 days (range 3–30 days). The reinfection rate was 27% in patients infected by *Staphylococcus epidermidis* who were treated for 7 days or less (four of 15 patients), and 28% in those who were treated for more than 7 days (five of 28 patients).

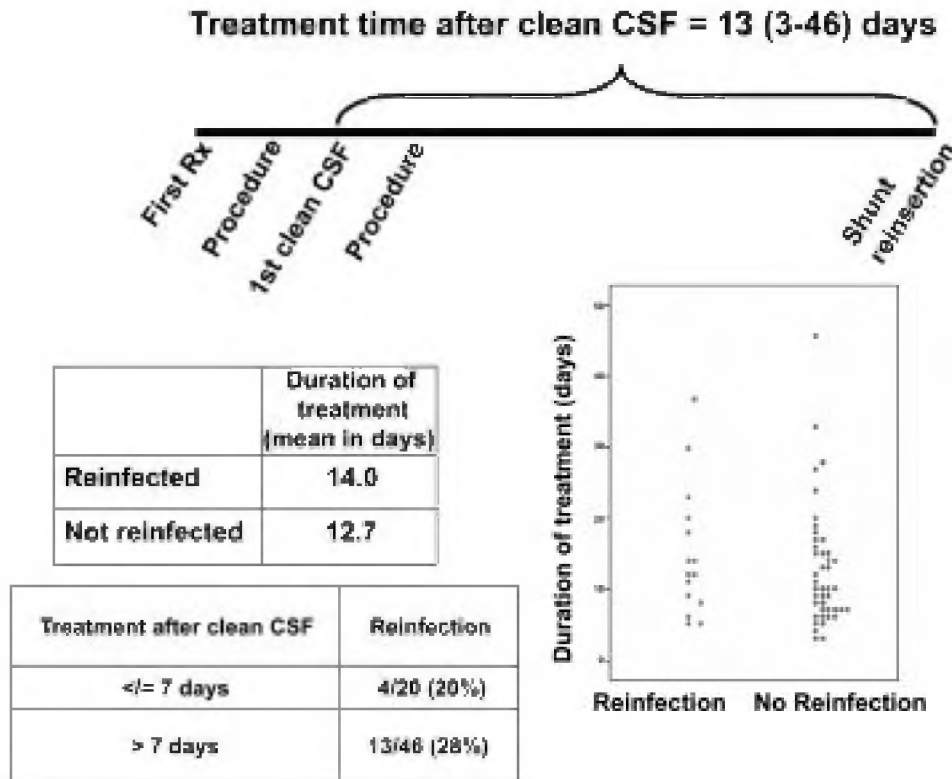


FIG. 2. Time line and charts demonstrating the treatment time after clean CSF and the incidence of reinfection.

Discussion

Because our previous observations⁸ were based on a case-scenario survey, our goal in this study was to obtain a more detailed picture of surgeons' actual clinical practice. The most remarkable finding is the alarmingly high incidence of recurrent shunt infection after treatment. Overall, the recurrence rate was 26%; two thirds of the recurrent infections were caused by the same organism and one third were due to a different organism. The recurrence rate after the treatment of *Staphylococcus epidermidis* infections was 29%. The most significant risk factor for recurrence of infection appeared to be a history of shunt infection within the preceding 6 months. A similarly high recurrence rate was found by Kulkarni, et al.⁶

The variation in the duration of antibiotic therapy is striking. This wide degree of variation occurred even among those patients who were not required to undergo intervening procedures to change the EVD. This is in agreement with our previously published survey of members of the American Society of Pediatric Neurosurgery.⁸ Eighty-four of 129 members responded to the case-based questionnaire. A great deal of intersurgeon variability in the duration of antibiotic therapy was observed. This was also true for specific organisms. For example, the duration of antibiotic therapy (after shunt removal and EVD placement) for *Staphylococcus epidermidis* infections ranged from 2 to 21 days.

Conclusions

Several of the findings in this pilot study deserve further examination. The high recurrence rate after treatment of

a shunt infection is difficult to accept, and methods to decrease it should be sought. Now that antibiotic-impregnated EVDs and shunt catheters are available, their role in the prevention and management of infection needs to be evaluated. It is possible that the use of such an EVD during treatment of an infection might more rapidly or more effectively clear the CSF of infection. On the other hand, specimens obtained from such an EVD might be less likely to exhibit growth of bacteria, resulting in undertreatment of the infection. A study in which antibiotic- and non-antibiotic-impregnated EVDs are compared during management of an infection therefore seems warranted. Another possible study would be to evaluate the role of antibiotic-impregnated shunt catheters at the time of shunt replacement after treatment of an infection. Such a study might be feasible given the fairly high recurrence rate of 26% demonstrated in this pilot study.

The extreme variability in the duration of antibiotic therapy and the lack of association between treatment time and recurrence suggest the potential for further work as well. The duration of antibiotic therapy determines the duration of hospital stay. In some centers, patients in whom an EVD has been placed stay in an intensive care unit; thus the cost of treatment of shunt infection can be quite significant. Because of the lack of association between duration of therapy and recurrence, the potential to decrease treatment time and, therefore, decrease hospital stay should be further investigated.

Appendix

The following persons and institutions participated in The Management of Shunt Infection (MOSI): A Multicenter Pilot Study. Note

Management of shunt infections

that the participating centers are listed in order of the number of eligible patients entered.

Primary Children's Medical Center, Salt Lake City, Utah

John R. W. Kestle, M.D., Marion L. Walker, M.D., and Douglas L. Brockmeyer, M.D.

University of Michigan, Ann Arbor, Michigan

Hugh J. L. Garton, M.D., and Karin M. Muraszko, M.D.

Riley Children's Hospital, Indianapolis, Indiana

William Whitehead, M.D., Jodi L. Smith, M.D., and Thomas G. Luerssen, M.D.

Hospital for Sick Children, Toronto, Ontario, Canada

James Drake, M.D., James T. Rutka, M.D., Robin P. Humphreys, M.D., Peter B. Dirks, M.D., Abhaya V. Kulkarni, M.D., and Maria Lamberti-Pasculli

University of California, San Francisco, San Francisco, California

Nalin Gupta, M.D., and Caroline Pearson, R.N.

Akron Children's Hospital, Akron, Ohio

Philipp Aldana, M.D.

British Columbia's Children's Hospital, Vancouver, British Columbia, Canada

Angela Price, M.D., Douglas Cochrane, M.D., and Paul Steinbok, M.D.

Children's Hospital of Wisconsin, Milwaukee, Wisconsin

Cheryl Muszynski, M.D., Bruce Kaufman, M.D., Barb Alivo, R.N., and Judeen Richleen, R.N.

Children's Hospital of Alabama, Birmingham, Alabama

W. Jerry Oakes, M.D., Paul Grabb, M.D., Jeffrey Blount, M.D., John C. Wellons, III, M.D., and R. Shane Tubbs, P.A.-C., Ph.D.

University of Mississippi Medical Center, Jackson, Mississippi

Andrew Parent, M.D., John Lancon, M.D., and Amanda Ellis, R.N.

References

1. Drake JM, Kestle JR, Milner R, Cinalli G, Boop F, Piatt J Jr, et al: Randomized trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus. **Neurosurgery** **43**:294–305, 1998
2. James HE, Walsh JW, Wilson HD, Connor JD, Bean JR, Tibbs PA: Prospective randomized study of therapy in cerebrospinal fluid shunt infection. **Neurosurgery** **7**:459–463, 1980
3. Kaufman BA: Management of complications of shunting, in McLone DG (ed): **Pediatric Neurosurgery: Surgery of the Developing Nervous System**, ed 4. Philadelphia: WB Saunders, 2001, pp 529–547
4. Kestle J, Drake J, Milner R, Sainte-Rose C, Cinalli G, Boop F, et al: Long-term follow-up data from the Shunt Design Trial. **Pediatr Neurosurg** **33**:230–236, 2000
5. Kestle JR, Drake JM, Cochrane DD, Milner R, Walker ML, Abbott R III, et al: Lack of benefit of endoscopic ventriculoperitoneal shunt insertion: a multicenter randomized trial. **J Neurosurg** **98**:284–290, 2003
6. Kulkarni AV, Rabin D, Lamberti-Pasculli M, Drake JM: Repeat cerebrospinal fluid shunt infection in children. **Pediatr Neurosurg** **35**:66–71, 2001
7. Patwardhan RV, Nanda A: Implanted ventricular shunts in the United States: the billion-dollar-a-year cost of hydrocephalus treatment. **Neurosurgery** **56**:139–145, 2005
8. Whitehead WE, Kestle JRW: The treatment of cerebrospinal fluid shunt infections. Results of a practice survey of the American Society of Pediatric Neurosurgeons. **Pediatr Neurosurg** **35**:205–210, 2001

Manuscript received December 22, 2005.

Accepted in final form May 26, 2006.

Address reprint requests to: John R. W. Kestle, M.D., Department of Neurosurgery, Primary Children's Medical Center, University of Utah, 100 N. Medical Drive, Salt Lake City, Utah 84113. email: john.kestle@hsc.utah.edu.