Decreasing ventricular infections through the use of a ventriculostomy placement bundle: experience at a single institution

Clinical article

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Object. Ventricular infection after ventriculostomy placement carries a high mortality rate. Responding to ventriculostomy infection rates, a multidisciplinary performance improvement team was formed, a comprehensive protocol for ventriculostomy placement was developed, and the efficacy was evaluated.

Methods. A best-practice protocol was developed, including hand hygiene before the procedure; prophylactic antibiotics; sterile gloves changed between preparation, draping, and procedure; hair removal by clipping for dressing adherence; skin preparation using iodine povacrylex (0.7% available iodine) and isopropyl alcohol (74%); full body and head drape; full surgical attire for the surgeon and other bedside providers; and an antimicrobial-impregnated catheter. A checklist of critical components was used to confirm proper insertion and to monitor practice. Procedure-specific infection rates were calculated using the number of infections divided by the number of patients in whom an external ventricular drainage (EVD) device was inserted × 100 (%). Data were reported back to providers and to the committee. Bundle compliance was monitored over a 4-year period.

Results. At the authors’ institution, 2928 ventriculostomies were performed between the beginning of the fourth quarter of 2006 and the end of the first quarter of 2012. Although the best-evidence bundle was applied to all patients, only 588 (20.1%) were checklist monitored (increasing from 7% to 23% over the study period). The infection rate for the 2 quarters before bundle implementation was 9.2%. During the study period, the rate decreased quarterly to 2.6% and then to 0%. Over a 4-year period, the rate was 1.06% (2007), 0.66% (2008), 0.15% (2009), and 0.34% (2010); it was 0% in 2011 and the first quarter of 2012. The overall EVD infection rate was 0.46% after bundle implementation.

Conclusions. Bundle implementation including an antimicrobial-impregnated catheter dramatically decreased EVD-related infections. Training and situational awareness of appropriate practice, assisted by the checklist, plus use of the antibiotic-impregnated catheter resulted in sustained reduction in ventriculitis.

Key Words • central nervous system infection • ventricular drainage • percutaneous surgery • quality improvement • care bundle • diagnostic and operative techniques

AN EVD device, or ventricular catheter, is placed into the cerebral ventricles, enabling drainage of CSF externally. It is typically connected by tubing to a CSF collection device that may be elevated or lowered at the bedside to vary the amount of CSF that is drained. These EVD devices are integral to the intensive care management of neurosurgical patients.10,14,25

Common indications for EVD device usage include management of hydrocephalus, elevated intracranial pressure or intracranial hemorrhage, and the intrathecal administration of medications.7,10,14,16,25,54 The EVD devices provide diagnostic information and can facilitate therapeutic CSF drainage.13,49,57 Despite their utility in the neurocritically ill, infection is a common complication of...
EVD use, resulting in increased length of ICU and hospital stay, and higher ICU and hospital costs as well as morbidity and mortality.48,58

The role of perioperative and prophylactic antimicrobial agents in the prevention of EVD-associated infections has been extensively discussed and debated. Most studies have shown that perioperative antibiotic prophylaxis is warranted in the initial 24 hours after device placement, but its benefit beyond that period remains uncertain.31,39-41 Antimicrobial-impregnated catheters have been manufactured for a variety of applications and have been shown to be effective in preventing EVD-associated infections.1,11,15,24,32,39,40,47 Current evidence suggests that antibiotic-impregnated catheters reduce the incidence of shunt infection.3,11,15,24,32,39,40,47 Other factors thought to be important in preventing infection include tunneling of the ventricular catheter, proper skin preparation for surgery, strict adherence to aseptic technique, use of a closed ventricular drainage system, and meticulous sterile nursing care.2,4,8,12,21,29,35,42,43,58

The Institute of Health Care Improvement has defined so-called care bundles as a structured way of improving the processes of care and patient outcomes by using a small, straightforward set of practices that have been recommended to decrease a complication—in this case health care–associated infections—when performed collectively.19,20,38

The objective of this quality improvement project was to study whether a ventriculostomy placement bundle, combining the aforementioned preventive factors, and implemented prospectively by a single institution with continuous feedback, would decrease the ventricular catheter–associated infection rate in our Neurointensive Care Unit.

Methods

This quality initiative was performed in the 30-bed Neurointensive Care Unit at Shands Hospital at the University of Florida, a 626-bed tertiary care academic medical center. The Neurointensive Care Unit was managed in a collaborative manner by a multidisciplinary team composed of neurointensivists, neurological surgeons, specialized nursing personnel, and other ancillary colleagues.

The Ventriculostomy Improvement Team was initiated during the summer of 2006, after a 9.2% infection rate for ventriculostomies alerted care givers in the Neurointensive Care Unit to the problem (Fig. 1). After the problem was recognized and the Ventriculostomy Improvement Team was empaneled in 2006, neurological surgery patients admitted to the Neurointensive Care Unit between the beginning of the fourth quarter of 2006 and the end of the first quarter of 2012 were enrolled, and 2928 ventriculostomies were placed and evaluated during this time period.

The intervention consisted of a preintervention observation period, development of standard procedures, and practitioner competence approved by a sign-off requirement before independently performing the procedure. Failure Mode Evaluation and Analysis77—a process by which process failures and risks are examined and remedial actions to mitigate these are developed—was used to identify failure modes and solutions, and to implement change and track results. Based on a broad literature review, evidence-based best practices were outlined and the care bundle was created and implemented.

The bundle consisted of a procedural checklist of critical components to teach proper insertion and to monitor practice; hand hygiene before the procedure; prophylactic antibiotics—as deemed appropriate by the clinician (oxacillin, cefazolin, or vancomycin); sterile gloves changed between preparation, draping, and performance of the procedure; hair removal by clipping for dressing adherence; skin preparation using iodine povacrylex (0.7% available iodine) and isopropyl alcohol (74%); full body and head drape; full surgical attire for the surgeon and other bedside providers; and an antimicrobial-impregnated catheter (Codman Bactiseal antimicrobial catheter system, Johnson & Johnson). The patient’s bedside nurse observed the procedure and contemporaneously completed the insertion checklist (Fig. 2) and was empowered to stop the procedure for any deviation from the recommendations; completed checklists were reviewed by the chief of the Division of Critical Care Medicine (A.J.L.) and the chair of the Department of Neurological Surgery (W.A.F.).

All patients requiring ventricular drainage catheter placement were eligible for this project. In the case of a patient with an initially infected ventricular drainage shunt, the infected catheter was removed and a new one placed if needed. This was considered a single infection; the fact that there was a second catheter was captured in “device days.” In the case of a patient with an initially infected EVD, the infected catheter was removed and a new one placed if needed. This would not be classified as an infection for the purposes of this paper because it was not related to the percutaneous ventricular catheter placement.

After training the Neurological Surgery residents and the Neurointensive Care Unit nurses, the bundle was implemented and all EVDs were placed at the bedside...
by the trained staff in accordance with the bundle. On review of the completed checklists, any placement errors documented by nursing staff led to a letter to the surgeon querying him or her about the observed error: Did it happen as documented? How did it happen? What was the method to be used to prevent it in future? A response was expected from the surgeon, and in no case was there a failure to respond.

The patients were tracked for development of EVD-related infection during the study period. The CSF was sampled when patients had fever or other signs and/or symptoms of infection. Ventricular infection was deemed present when the CSF culture was positive, with increase in CSF white blood cells; infection was also deemed present when there was an increase in CSF white blood cells with clinical signs of infection in the setting of negative CSF culture. The infection rate was obtained via ongoing and sustained surveillance. One individual (L.A.) made every diagnosis according to the same criteria. The infection rate was calculated by the following equation: Infection rate (%) = number of infections/number of patients with an EVD × 100.

Data were reported back to the surgeons and the Ventriculostomy Improvement Team at our monthly meetings. Because this was a quality improvement project, it was determined that informed consent was not needed.

Results

Between the beginning of the fourth quarter of 2006 and the end of the first quarter of 2012, 2928 ventriculostomies were placed. The patients’ mean age was 56 years, with a male/female ratio of 1:1.4. Of the 2928 patients, only 588 (20.1%) were checklist monitored—increasing from 7% to 23% over the entire quality improvement project period—with only 477 checklists having complete data. In total, 43 infections (1.5%) in 2928 placements were identified; 41 (95%) of them were culture positive and 2 were culture negative. Coagulase-negative staphylococci (13 cases, 31.7%) and Acinetobacter baumannii (6 cases, 14%) were the most frequent microorganisms isolated from the cultures (Table 1). Only 1 Candida species infection was identified. When time from ventriculostomy placement to infection occurrence was examined, the number of infections was highest (37%) 8–14 days after insertion; the rate decreased after Day 15, and only 1 case was identified after Day 25 (Table 2).

The infection rate before bundle implementation was

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**Fig. 2.** The ventriculostomy insertion checklist developed for the project. This incorporated best-practice data where available.
TABLE 1: Organisms associated with ventricular infections in 41 patients who underwent ventriculostomies*

<table>
<thead>
<tr>
<th>Organism</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acinetobacter baumannii</td>
<td>6</td>
</tr>
<tr>
<td>A. lwofii</td>
<td>2</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>3</td>
</tr>
<tr>
<td>Pseudomonas species</td>
<td>1</td>
</tr>
<tr>
<td>Enterobacter cloacae</td>
<td>2</td>
</tr>
<tr>
<td>E. aerogenes</td>
<td>1</td>
</tr>
<tr>
<td>Klebsiella pneumoniae</td>
<td>1</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>2</td>
</tr>
<tr>
<td>Candida albicans</td>
<td>1</td>
</tr>
<tr>
<td>coagulase-negative staphylococci</td>
<td>13</td>
</tr>
<tr>
<td>MRSA</td>
<td>3</td>
</tr>
<tr>
<td>Enterococcus faecalis</td>
<td>2</td>
</tr>
<tr>
<td>E. faecium</td>
<td>1</td>
</tr>
<tr>
<td>Streptococcus viridans</td>
<td>1</td>
</tr>
<tr>
<td>vancomycin-resistant enterococci</td>
<td>1</td>
</tr>
<tr>
<td>Streptomyces species</td>
<td>1</td>
</tr>
</tbody>
</table>

* MRSA = methicillin-resistant S. aureus.

9.2%. During the study period the rate decreased quarterly, to 2.6% and then to 0%. Over the 4-year project period, the yearly infection rate was 1.06% (2007), 0.66% (2008), 0.15% (2009), and 0.34% (2010); it was 0% from the last quarter of 2010 through the end of the first quarter of 2012. The overall EVD infection rate was 0.46% after bundle implementation (Fig. 3). Although the insertion checklists were not completed as was hoped, there were no protocol violations seen during the EVD placements for which there were checklists. All staff had completed training and were provided with feedback on the infection rates.

**Discussion**

This paper shows the effectiveness of implementing an evidence-based bundle to decrease—indeed eliminate—an iatrogenic infectious complication. We noted that our ventricular infections decreased from 9.2% to essentially 0% over a 4-year period; these rates remain at 0% today. Of particular note, the rate began to drop dramatically when attention was focused on the problem. The importance of compliance with the bundle appears to have been noted and adopted as part of the culture of safety in light of the sustained ongoing 0% infection rate.

An EVD-related infection is a common complication after ventriculostomy.3,5,46,21,35 The rate of EVD-related infection has been reported to be up to 27%,7,16,18,21,23,35,36,45 with differences in the definition of infection potentially impacting this figure. The role of perioperative and prophylactic administration of antimicrobial agents in the prevention of EVD-associated infections has been extensively discussed and debated. Alleyne et al.2 reviewed more than 300 patients who received either daily prophylactic antimicrobials or perioperative antimicrobials alone, finding no significant difference in the infection rate between the 2 groups. Although there are no randomized controlled trials addressing this practice, a meta-analysis39 of 15 observational studies demonstrated the benefit of systemic prophylactic antibiotics for the first 24 hours postoperatively to prevent shunt infection, regardless of the patient’s age and the type of internal shunt used, although the benefit of antibiotic use after this period remains uncertain.31,39–41 Furthermore, it has been suggested that prolonged prophylactic antibiotics may lead to resistant or opportunistic pathogens such as methicillin-resistant S. aureus and Candida species.36

Antibiotic-impregnated catheters were included in the bundle because current evidence suggests that they reduce the incidence of shunt infection.1,15,24,32,39,40,47 In a randomized trial of 288 device placements, the antibiotic-impregnated catheters were found to be one-half as likely to become colonized as the control catheters (17.9% compared with 36.7%, respectively; p < 0.0012). Positive CSF cultures were 7 times less frequent in patients with antibiotic-impregnated catheters compared with those in the control group (1.3% compared with 9.4%, respectively; p = 0.002).2 Another significant reduction in shunt infection with these catheters was also noted in the previously mentioned meta-analysis.39 Another study showed that antibiotic-impregnated catheters provided an additional decrement in EVD-related infections in the context of a minimal handling protocol consisting of catheter placement in the operating room, preoperative antibiotic prophylaxis, and catheter exchange when CSF pleocytosis was confirmed or a positive CSF culture persisted in spite of an appropriate intravenous antibiotic treatment.46 Additionally, using silver-impregnated EVDs is also reported to decrease positive CSF cultures, colonization of the catheter tip, or CSF pleocytosis by 50%.12 This general approach mimics the sustainable decrease in central line–associated infections demonstrated when an antibiotic-impregnated central venous catheter was added to a central line infection prevention bundle. Rates of infection of up to 27% have been reported in EVD catheter placement.7,9,16,18,21,23,35,47 Risk factors for the development of EVD-associated ventriculomeningitis include EVD duration greater than 11 days, frequency of CSF sampling, intraventricular hemorrhage, surgical technique (subcutaneously tunneled EVD, Rickham reservoir with percutaneous CSF drainage), neurosurgical operative procedure, and irrigation or manipulation of the drainage.
Conflicting data exist regarding the association between duration of ventricular drainage and the rate of EVD-associated infections. Some clinical series have shown a linear relationship between infection and duration of the ventricular drainage catheter, whereas others have suggested that the duration of monitoring is not a risk factor associated with infection. In fact, later studies have shown that a constant daily rate of infection actually decreases after Day 10 or 11 of drainage. Our data suggest that the highest incidence of infection occurs between Days 4 and 14, which is not completely inconsistent with what has been previously found.

The effective use of all components of care bundles has been found to be successful in reducing rates of health care–associated infection. When adjusted for device use, the decrease in infection rates continued to be statistically significant, beyond the impact of device removal. This finding was replicated in catheter-related bloodstream infections, ventilator-associated pneumonia, and urinary tract infections in different ICU settings. Although there are many studies addressing significant factors in preventing EVD-associated infection, few have evaluated the effect of a strict insertion protocol on the EVD-related infection rate. Our study shows that implementation of a strict insertion bundle, including application of antibiotic-impregnated catheters, can significantly decrease the EVD-related infection rate.

Our results are encouraging but some limitations must be acknowledged. First, this is a single-center study and, even though the bundle elements were followed in all patients as evidenced by the significant and sustained infection decrease, only a minority of the EVD catheter insertions were placed using the insertion checklist. Additionally, we are not able to separate out the impact of each of the different best-practice elements, because they were implemented en bloc in response to a patient safety and quality of care issue. Finally, drawing a CSF sample through an antibiotic-impregnated catheter has been reported in 1 study to potentially cause false-negative culture results; if this is of any significance, further studies will be required.

One last issue must be at least briefly mentioned. A checklist does not improve quality. Rather, the checklist is only the visual manifestation of a change from a “culture of impunity” to a “culture of safety.” We did not find that there were significant bundle implementation barriers; we did, however, have a problem with the implementation of the checklist itself, the visible manifestation of the changes we were making. Despite this, the data we have provided speak to the changes made in our unit.

### Conclusions

We found a significant decrease—from 9.2% to 0% over 4 years—in EVD-related infections in our institution on implementation of an insertion bundle that included training of staff, strict hygienic measures, full surgical draping, use of prophylactic antibiotics, feedback of infection rates to the care team, and use of an antimicrobial-impregnated catheter.

### Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Layon, Fauerbach, Archibald, Friedman. Acquisition of data: Fauerbach, Archibald. Analysis and interpretation of data: Layon, Amini, Archibald. Drafting the article: Layon, Kubilay, Amini, Archibald, Friedman. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Layon. Statistical analysis: Archibald, Friedman. Administrative/technical/material support: Fauerbach, Friedman. Study supervision: Fauerbach, Archibald.

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### References

1. Abla AA, Zabramski JM, Jahnke HK, Fusco D, Nakaji P. Comparison of two antibiotic-impregnated ventricular catheters: a
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