Ventriculoperitoneal (VP) shunt infections are a common complication in patients with these devices. Because children with cerebrospinal fluid (CSF) shunts are more likely to experience infections, considerably more studies evaluating this complication in children are available than studies evaluating this complication in adults.1–3 The available literature on VP shunt infections in adults consists mainly of retrospective chart reviews and case reports, making it difficult to determine the optimal care these patients should receive when they have an acute infection. As a result of the potential complications of VP shunt infections, patients often are treated in the intensive care unit and nurses play a major role in ensuring the optimal care for these patients. This column summarizes the published data describing the incidence and risk factors, microbiology, diagnosis, treatment, and prevention of VP shunt infections in adult patients.

**VP Shunts**

Cerebral shunts are primarily used to manage hydrocephalus, a condition in which a buildup of excess CSF accumulates in the ventricles of the brain. The use of cerebral shunts to manage hydrocephalus dates back to the mid-20th century.4 Left untreated, hydrocephalus can lead to increases in intracranial pressure, cerebral edema, and ultimately herniation of brain tissue. Various types of cerebral shunts are available, and they are classified by name, according to where the distal end of the shunt catheter routes CSF, or by valve type.5 Examples of different types of shunts include ventriculoatrial, ventriculopleural, and VP. Ventriculoperitoneal shunts route excess CSF from the ventricles into the peritoneal space. Conditions that routinely require the placement of VP shunts are listed in Table 1.

Complications resulting from VP shunt placement are common, particularly early after placement. Following VP shunt placement, the 1-year shunt failure rate is approximately 40%, and the 2-year shunt failure rate has been reported to be as high as 50%.3 Complications include intraventricular hemorrhage, obstruction, overdrainage of CSF, and infection. Among these complications, infection is one of the most serious, often requiring prompt management.

---

Diana L. Wells is Assistant Clinical Professor, Department of Pharmacy Practice, Auburn University Harrison School of Pharmacy, 1321 Walker Bldg, Auburn, AL 36849 (diana.wells@auburn.edu).

John M. Allen is Assistant Clinical Professor, Department of Pharmacy Practice, Auburn University Harrison School of Pharmacy, and Adjunct Assistant Professor, Department of Surgery, University of South Alabama College of Medicine, Mobile, Alabama.

The authors declare no conflicts of interest.

DOI: 10.1097/NCI.0b013e31827be1d1

Copyright © 2013 American Association of Critical-Care Nurses. Unauthorized reproduction of this article is prohibited.
Incidence and Risk Factors for Infection

Hydrocephalus that requires the placement of a VP shunt may occur for many reasons, but the cause of hydrocephalus does not seem to affect the risk for shunt infection. The incidence of VP shunt infections in adults is between 1.6% and 16.7%. Such wide ranges of infection rates are due in part to varying definitions of shunt infections and patient demographics reported throughout the literature. Presently, no guideline recommendations are available for the diagnosis of a CSF shunt infection; however, standardized approaches have recently been proposed.

The highest rate of shunt infection occurs early after shunt placement or revision (eg, within 1 month); therefore, most contamination with microorganisms is thought to occur intraoperatively. The infection rate increases with the number of surgical revisions. In fact, adult patients with previous revisions for mechanical shunt dysfunction are 3 times more likely to develop an infection than those who have not undergone any surgical revisions. These numbers are important to consider because an estimated 50% or more of all patients with a CSF shunt require at least 1 surgery for revision.

Some evidence also suggests that a history of craniotomy or external ventricular drain (EVD) prior to shunt placement doubles the risk for shunt infection. Despite the limited evidence, healthcare providers can reasonably consider these procedures as possible risk factors, given that both procedures have the potential to introduce microorganisms into the sterile environment of the CSF. Other risk factors include younger age, holes in surgical gloves, postoperative CSF leak, and shunt insertion performed by neurosurgeons with limited experience.

Microbiology

Shunt infections are often the result of contamination of the proximal end of the shunt with normal skin flora. Among these flora, coagulase-negative *Staphylococci* and *Staphylococcus aureus* are the most common pathogens associated with the development of VP shunt infection. Infections caused by these pathogens account for 50% and 33% of all shunt infections, respectively.

Timing of the infection appears to be related to the specific microbiology of VP shunt infection. Early VP shunt infections (within weeks of insertion and revision) are typically caused by skin flora, such as coagulase-negative *Staphylococci* and *S. aureus*. However, late VP shunt infections (several months after insertion and revision) are usually caused by *Streptococcus* spp and gram-negative pathogens, such as *Pseudomonas aeruginosa*, and occur as a direct result of bowel perforation or peritonitis. Other rare pathogens associated with late VP shunt infections include *Candida albicans*, *Corynebacterium jeikeium*, and *Mycobacterium* spp.

Table 1 lists additional pathogens associated with VP shunt infections.

Diagnosis

Initially, a VP shunt infection may not elicit obvious neurological symptoms. However, symptoms can develop when the infection causes shunt obstruction and subsequent...
increases in intracranial pressure. These symptoms include headache, nausea, vomiting, and altered mental status.

Clinical suspicion for a VP shunt infection warrants evaluation of CSF, blood cultures, and neuroimaging studies. Cerebrospinal fluid for analysis should be obtained directly from the VP shunt rather than via lumbar puncture, if possible, and should include white blood cell (WBC) count with differential, glucose, and protein concentrations. Gram stain and CSF culture should also be performed because identification of pathogens is necessary for successful directed antibiotic therapy.

A positive CSF analysis will yield elevations in WBC count (1000-5000/mcL), with a high percentage of neutrophils (>80%) and protein concentration (100-500 mg/dL). Cerebrospinal fluid glucose concentrations are usually decreased (<40 mg/dL). Clinicians should note that interpretation of CSF analysis may be more difficult in certain circumstances. For example, traumatic lumbar puncture, generalized seizures, or intracerebral or subarachnoid hemorrhage may cause spurious elevations in CSF WBC count.

The use of blood cultures to help diagnose shunt infections has been shown to yield inconsistent results. Previous studies report positive blood cultures in only 23% of VP shunt infections, whereas 95% of ventriculoatrial shunt infections produced positive blood cultures.

Neuroimaging is useful to identify ventriculitis and obstruction of CSF. Abdominal imaging can also be used to help identify blockage of the distal end of the shunt. Recently more standardized diagnostic criteria for definite and probable shunt infections have been proposed and are summarized in Table 3.11

### Treatment

Most infections arise from skin flora rather than from an abdominal source, resulting in an infection of the central nervous system (CNS). Because meningitis is a common result of VP shunt infections, a strong emphasis on appropriate treatment is needed.1,12,13,14 Although the management of VP shunt infections is not standardized, the Infectious Diseases Society of America’s guidelines offer some direction in the treatment approach for patients with meningitis who have a CSF shunt. The management of the infection often involves the removal of the infected shunt with placement of a temporary EVD if needed, culture of various sites (wound, shunt tip, CSF from valve, ventricular CSF, lumbar CSF, and/or blood), and treatment with intravenous and possibly intraventricular antibiotics.

Because the distal end of a VP shunt lies within the peritoneal cavity, the risk for infection with gram-negative bacteria is also a possibility, and empiric antibiotic choices should include coverage for these pathogens.23,24

#### Systemic Antibiotics

Most VP shunt infections require treatment with systemic antibiotics. For empiric antibiotic selection, the clinician should assume that antimicrobial resistance is a possibility and choose broad-spectrum coverage until culture identification and susceptibility data are available. Current guidelines recommend combination therapy with vancomycin plus one of the following agents: cefepime, ceftazidime, or meropenem.21 Common dosing requirements for these antibiotics are listed in Table 4. The antibiotic choice and dosing are based on the need for adequate penetration of the drug into the CSF for bactericidal efficacy against the infection in the setting of meningitis.21

#### Intraventricular Antibiotics

In patients with infections that are difficult to cure or in those who cannot undergo removal of the infected shunt, the current guidelines recommend that clinicians consider direct administration of antibiotics into the ventricles.23 Note that the specific indications for intraventricular
shunt was not removed were associated with a significant increase in the number of subsequent shunt revisions due to complications from the infection (eg, blockage of the distal catheter). On the basis of these findings, the authors concluded that the treatment combination of shunt removal, 20 mg/d of intraventricular vancomycin, and systemic antibiotics was both safe and effective for CSF shunt infections.

In another case series of adult and pediatric patients, Swayne et al describe their results with a similar treatment approach to Bayston and colleagues. Twenty episodes of CSF shunt infections in 15 patients were treated with shunt removal, placement of an EVD, and intraventricular vancomycin (adults: 20 mg/d [n = 6]; pediatric patients: 10 mg/d [n = 9]). One of the major differences in this treatment approach from the previous is the placement of an EVD, which allowed both access to the ventricle for antibiotic administration and control of CSF pressure for the duration of treatment. Similar to the previous study, most patients received concomitant systemic antibiotics, including vancomycin, gentamicin, flucloxacillin, trimethoprim, and cotrimoxazole. Antituberculosis antibiotics were also administered for 3 of the reported infections; however, the names of these antibiotics were not reported. Interestingly, intraventricular vancomycin was the only antibiotic administered in 4 of the study patients. All study patients, however, had follow-up CSF samples that were sterile and free of pus, suggesting that the treatments led to an acute resolution of CSF shunt infections.

Table 4: Common Intravenous Antimicrobial Treatment Regimens for Ventriculoperitoneal Shunt Infections Based on Causative Pathogen

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Treatment of Choice</th>
<th>Common Intravenous Dosing Requirements (Normal Renal Function)</th>
<th>Treatment Duration, d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulase-negative <em>Staphylococci</em> (eg, <em>S epidermidis</em>)</td>
<td>Vancomycin</td>
<td>15 mg/kg every 8-12 h</td>
<td>7</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>MRSA: Vancomycin</td>
<td>15 mg/kg every 8-12 h</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>MSSA: Nafcillin</td>
<td>2 g every 4 h</td>
<td></td>
</tr>
<tr>
<td>Gram-negative bacilli (eg, <em>P aeruginosa</em>)</td>
<td>Ceftazidime</td>
<td>2 g every 8 h</td>
<td>10-14; depending on clinical response</td>
</tr>
<tr>
<td></td>
<td>Cefepime</td>
<td>2 g every 8 h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meropenem</td>
<td>2 g every 8 h</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-sensitive *Staphylococcus aureus*.

*Based on information from meningitis guidelines and Tunkel et al. 23,24

Antibiotic administration have not been defined. Limited data are available for the use of intraventricular antibiotics for the treatment of VP shunt infection in adults, and no antibiotics are currently approved for this use by the Food and Drug Administration. However, this practice is used often in the clinical setting on the basis of several case reports. 18,23,26

Vancomycin is the most widely studied antibiotic for intraventricular administration in adults. In a retrospective case series by Bayston et al, 50 cases of ventriculitis caused by CSF shunt infections in pediatric and adult patients were treated with intraventricular vancomycin. Cerebrospinal fluid culture data revealed that all infections were susceptible to vancomycin, and the most commonly identified pathogen was coagulase-negative *S aureus*. Doses ranged from 5 to 20 mg once daily; however, most patients (76%) received 20 mg/d. Lower doses were primarily used in the pediatric population. Because of the retrospective study design, the treatment regimens were not standardized, and most patients received a combination of approaches, including intravenous, intraventricular, and oral antibiotics in addition to shunt removal and/or placement of an EVD. Treatment continued up to 3 to 4 days after negative CSF cultures were obtained. Follow-up to determine treatment success occurred between 3 months and 4 years after antibiotics were discontinued. The overall cure rate was 66%; however, those who received the treatment combination of shunt removal, 20 mg of intraventricular vancomycin daily, and systemic antibiotics experienced a 92% cure rate, and no reports of vancomycin toxicity were noted. Infections in which the CSF shunt was not removed were associated with a significant increase in the number of subsequent shunt revisions due to complications from the infection (eg, blockage of the distal catheter). On the basis of these findings, the authors concluded that the treatment combination of shunt removal, 20 mg/d of intraventricular vancomycin, and systemic antibiotics was both safe and effective for CSF shunt infections. 25
and not all isolates were sensitive to the systemic antibiotics used, which suggests that the intraventricular antibiotic alone was effective in many reported cases; the authors concluded that in uncomplicated cases of shunt infections with gram-positive cocci, monotherapy with intraventricular vancomycin is an effective treatment option.26

Knudsen et al26 described their success with intraventricular vancomycin for the treatment of VP shunt-related ventriculitis due to Corynebacterium jeikeium in a 52-year-old woman. After an unsuccessful treatment regimen with intravenous vancomycin (1 g intravenously every 12 hours), the patient was subsequently treated with shunt removal and intraventricular vancomycin (10 mg/d for 4 days), followed by oral rifampin and fusidic acid. The total duration of treatment was 15 days. As of 1 year after discharge, the patient did not experience any relapse of infection.18

In summary, for complicated VP shunt infections (eg, meningitis), clinicians should consider administration of intraventricular antibiotics in addition to systemic antibiotics, preferably after the infected shunt has been removed, as cure rates are highest with this treatment approach.18,23–26 Both systemic and intraventricular antibiotics should be de-escalated to target the causative pathogen on the basis of the available culture and sensitivity data. Uncomplicated infections may be treated successfully with intraventricular vancomycin alone if a susceptible pathogen is identified from the CSF or drain culture.

Many other antimicrobial agents, including aminoglycosides and colistin, have been administered intraventricularly.23 Table 5 summarizes the recommended dosages for intraventricular use of these agents. The optimal dosing strategy is not well established; however, maintaining trough CSF concentrations of at least 5 to 10 times the minimum inhibitory concentration of the causative pathogen is recommended. Although no clear recommendation exists for duration of treatment with intraventricular antibiotics, clinical signs of infection should be resolved and negative CSF cultures should be obtained prior to discontinuation.23,27

Prophylactic Antibiotics to Aid in Prevention of Infection
Current guidelines for the use of perioperative antibiotics recommend cefazolin for clean procedures (ie, an uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, genital, or uninfected urinary tract is not entered) such as CSF shunt insertion. If a patient is allergic to cephalosporin agents, clinicians are recommended to use an alternative agent such as vancomycin for gram-positive coverage.26 However, primary literature in support of this recommendation, specifically for CSF shunt insertion in adult patients, is lacking.

In light of the increasing incidence of methicillin-resistant strains of Staphylococcus aureus, Tacconelli et al27 compared infection rates in adult patients who received vancomycin 1 g intravenously over 60 minutes (n = 88) versus cefazolin 1.5 g intravenously over 30 minutes (n = 88) prior to CSF shunt implantation in a prospective, randomized trial. Patients in the cefazolin group received doses every 4 hours until surgery was completed. By 4 weeks after the procedure in an intention-to-treat analysis, shunt infections developed in 4 patients who received vancomycin (4.5%) and 12 patients who received cefazolin (13.6%) (relative risk: 0.27; 95% confidence interval: 0.44–0.04; P = .04). The duration of postsurgical hospitalization was longer (mean ± SD: 38 ± 37 vs 54 ± 78 days, respectively; P = .03) and the mortality rate among patients with postsurgical infections was greater (number: 0

Table 5: Recommended Dosages of Antimicrobial Agents Administered by the Intraventricular Route a,b

<table>
<thead>
<tr>
<th>Antimicrobial Agent</th>
<th>Daily Intraventricular Dose, mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gentamicin</td>
<td>1–8 b</td>
</tr>
<tr>
<td>Tobramycin</td>
<td>5–20</td>
</tr>
<tr>
<td>Amikacin</td>
<td>5–50 a</td>
</tr>
<tr>
<td>Polymyxin B</td>
<td>5 a</td>
</tr>
<tr>
<td>Colistin</td>
<td>10</td>
</tr>
<tr>
<td>Quinupristin/dalfopristin</td>
<td>2–5</td>
</tr>
<tr>
<td>Teicoplanin</td>
<td>5–40 a</td>
</tr>
</tbody>
</table>

a Used with permission from Tunkel et al.23
b There are no specific data that define the exact dose of an antimicrobial agent that should be administered by the intraventricular route.

Copyright © 2013 American Association of Critical-Care Nurses. Unauthorized reproduction of this article is prohibited.
of adult patients who had undergone CNS shunt infections. In a retrospective study period, 39% of Staphylococci isolated from the CNS shunt infections during the study period were methicillin resistant. Given the lower incidence of infection, shorter hospital stay, and lower overall mortality rate from postsurgical infections in patients who received vancomycin, this study supports the routine use of intravenous vancomycin rather than cefazolin prior to CNS shunt insertion for infection prophylaxis. These findings would likely best be applied in clinical settings of adult patients with similar rates of methicillin-resistant Staphylococci. Currently, no other prospective, randomized studies are available to confirm the findings of Tacconelli et al. 29  Intraventricular antibiotic administration also has been evaluated for prophylaxis of CNS shunt infections. In a retrospective study of adult patients who had undergone CNS shunt implantation for hydrocephalus, Ragel and colleagues 12 compared the risk of shunt infections among groups of patients who had received various methods of antibiotic prophylaxis. A total of 802 procedures for shunt placement were performed in 534 patients during the study period. All patients received intravenous antibiotic prophylaxis with 1 to 2 g of cefazolin or 1 g of vancomycin prior to skin incision, with doses typically continued for 24 hours after the procedure. In addition, some patients received intraventricular antibiotic prophylaxis. Patients were observed for 90 days following shunt implantation to evaluate the incidence of infection. The authors compared outcomes for 4 groups of patients: group 1, 4 mg of intraventricular gentamicin (before May 16, 1999); group 2, 4 mg of intraventricular gentamicin plus 10 mg of intraventricular vancomycin (after May 16, 1999); and 2 control groups who did not receive intraventricular antibiotic prophylaxis (groups 3 and 4: before and after May 16, 1999, respectively). Patients who received both intraventricular gentamicin and vancomycin had significantly fewer infections than patients in all other groups (percentage of patients with infections in groups 1–4 were 5.45%, 0.41%, 6.21%, and 6.74%, respectively). No decrease in infection rate was observed in patients who received only intraventricular gentamicin; therefore, the authors concluded that the combination of intraventricular gentamicin and vancomycin was an effective method to prevent CNS shunt infection. 12  Whether antibiotic prophylaxis for VP shunt placement should be routinely used in adults is debatable, given the lack of well-controlled studies and guideline recommendations. A Cochrane review from 2006, which evaluated trials involving all age groups, indicated a significant difference in favor of systemic antibiotic prophylaxis for up to 24 hours following the placement of internal CNS shunts. 30  Clinicians are advised to administer antibiotic prophylaxis for VP shunt insertion; however, well-controlled trials evaluating the efficacy of this practice in preventing infections are needed.

Another method of infection prevention is using antibiotic-impregnated shunts, a practice that has been evaluated in several studies. 30–32  The efficacy of antibiotic-impregnated shunts has not been consistently demonstrated; therefore, the use of these devices is not the standard of care.

Conclusion
The appropriate diagnosis, treatment, and prevention of infections are important elements to optimize care for adult patients with VP shunt infections. In the setting of CSF shunt infections, objective information from the patient’s physical examination and available culture data should be used to guide treatment. Initial systemic antibiotic selection should cover a broad range of pathogens, followed by de-escalation of antibiotics once the microorganism is identified. The best treatment results occur when antibiotics are administered in addition to device removal. Certainly, further studies are needed in this patient population to determine the most appropriate treatment approach.

REFERENCES
Drugs Update


