

# Ventriculostomy-Associated Infection: A New, Standardized Reporting Definition and Institutional Experience

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## Abstract

**Objective** Shortcomings created by the lack of both a uniform definition of ventriculostomy-associated infection (VAI) and reporting standards have led to widely ranging infections rates (2–24 %) whose significance is uncertain. We propose a standardized definition of VAI and a consistent reporting format compliant with Centers for Disease Control and Prevention (CDC) for device-related infections. Using those parameters to establish an infection-control surveillance program, we report our 4-year institutional VAI rates.

**Methods** In this prospective study covering ventriculostomy utilization (October 2006–December 2010), 498 patients had a total of 4,673 ventriculostomy days. By review of the literature and our institutional analysis, we defined VAI as a positive CSF culture in a patient with ventriculostomy catheter, *plus* one or more of the following

(1) fever recorded  $>101.5$  °F or (2) cerebrospinal fluid (CSF) glucose level, either  $<50$  mg/dL or  $<50$  % of a serum glucose level drawn within 24 h of the CSF glucose. In a report format that is CDC compliant, rates of VAI are reported.

**Results** Among our patients, the CDC-compliant infection rate was 2.14 per 1,000 ventriculostomy days. Of the 10 VAIs occurring in 498 patients during 4,673 ventriculostomy days, this 2.0 % infection rate was lower than the previously reported 8.8 % composite rates of VAI. Average duration of ventriculostomy was 9.4 days. Neither antibiotic-impregnated catheters nor perioperative or prophylactic antibiotics were used.

**Conclusions** Our standardized VAI definition and CDC format seems promising toward facilitating future study and guideline development. Given our strict protocol of sterile catheter placement and care, and our institution's low 2.0 % infection rates, we propose an infection-rate target of  $\leq 5$  per 1,000 device days. Our results suggest that the use of antibiotics or antibiotic-impregnated catheters is unwarranted—a positive given concerns of evolving antimicrobial resistance.

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## Introduction

Ventriculostomies are a mainstay of modern neurosurgical care for a multitude of pathologic processes in which monitoring intracranial pressure or drainage of cerebrospinal fluid (CSF) is necessary for optimal patient care. However, the use of these external ventricular drains (EVDs) is associated with an array of complications,

including life-threatening infections. The underlying risk factors for ventriculostomy-associated infections (VAIs), which are well-documented in the literature [1–5], include prolonged catheter use, manual manipulation of the catheter for drainage or irrigation, or distal disconnection of the extracranial tubing system. Moreover, an increased risk of catheter-associated infections is often observed in patients with concurrent systemic infection, intraventricular hemorrhage, subarachnoid hemorrhage, or in the context of CSF leak. These iatrogenic infections can result in devastating neurologic sequelae that necessitate prolonged allocation of intensive care resources [6].

Incidence of VAI has varied widely in published reports, ranging from 2 to 24 % [4, 7–9] with an average of 8.8 % [4]. This range likely stems, in part, from inconsistencies in the criteria used to define VAI, and thus contributes to the difficulties in prospective monitoring of institutional infection rates and demonstrating efficacy of new devices. Although the Centers for Disease Control and Prevention (CDC) has established guidelines for standardized reporting of health-care associated infections [10], to date, only one study in the neurosurgical literature has attempted to apply these recommendations to VAI reporting [11].

In this study, we propose a uniform definition of VAI and recommend a standardized method of reporting that complies with CDC guidelines for device-related infections. Using our standardized definition and CDC format, we report the incidence of VAI during a 4-year period at our academic tertiary care hospital and level-1 trauma center.

## Methods

In this prospective study, the authors refine a definition previously proposed by Lozier et al. [4] to examine rates of VAI from October 2006–December 2010 for 498 patients who underwent EVD placement. The study was approved by the University of Cincinnati Institutional Review Board.

### Ventriculostomy-Associated Infection Definition

VAI was defined as a single positive CSF culture in a patient with a ventriculostomy catheter, *plus* one or more of the following minor criteria: (1) Fever (recorded temperature exceeding 101.5 °F), or (2) CSF glucose level either <50 mg/dL or <50 % of a serum glucose level drawn within 24 h of the CSF glucose. In order to maximize our sensitivity for VAI, a positive culture was determined by any reported bacterial growth. Institutional reporting included patients in whom the above criteria were met within 72 h of EVD removal. Excluded patients had a positive CSF culture obtained at the time of EVD insertion

because these infections were not specifically catheter-related. A specific patient could potentially have more than one VAI if multiple organisms were concomitantly isolated. This definition closely follows previously proposed criteria [4, 12, 13].

### Surveillance and Data Collection

A practitioner in the Neurosurgical Intensive Care Unit (NSICU) or infection control department prospectively collected the following data: patient name, medical record number, EVD catheter type used, dates of EVD insertion and removal, number of device days, and date(s) of diagnosis of VAI(s) that met our proposed definition. By protocol, CSF was sampled twice weekly for the duration of EVD use. Additional samples were obtained at the discretion of the treating physician. The CSF was analyzed for cell count with differential, protein, and glucose. Moreover, 2 mL of CSF were sent specifically for gram stain and bacterial culture.

### Standardized Nursing Care Protocols

Post-placement ventriculostomy care in the intensive care setting was standardized to minimize risks for infection. First, all EVDs were maintained in a sterile occlusive dressing, which was replaced as needed under sterile precautions to maintain a clean occlusive covering. Hair growth in the sterilized scalp was clipped with a sterile clipper head to ensure proper application of the adhesive dressing. During all dressing changes, the affected scalp was repped with a chlorhexidine gluconate/isopropyl alcohol swabstick. After removing any dried blood or debris with the swab stick, the area around the catheter site was scrubbed for 30 s using the swab's other side, being careful not to contact the catheter's insertion point. When dry, the prepped scalp was painted, working from center to periphery, with adhesive skin prep. Subsequent application of benzoin enhanced the dressing adherence to the patient's scalp also reduced infection risk by minimizing the number of dressing changes required. Finally, the catheter was placed so as to avoid kinking or excessive tension during any normal head movements or positions; a transparent dressing was applied to completely seal the catheter length that projected to the drainage tubing. Outside of this dressing, the drainage tubing was secured with adhesive strips and/or tape. Importantly, ICP waveform and patency of the catheter were assessed after every dressing change. If this waveform was disrupted or if CSF drainage stopped, an assessment was performed and a physician was notified so that repositioning the stopcocks and/or straightening any kinks or obstructions could be done in the catheter system. A physician was also notified regarding concerns of CSF

leakage (e.g., dampness within the EVD dressing) or signs of infection such as pain, erythema, or drainage at the EVD insertion site.

Occlusive dressing of the ventriculostomy catheter was maintained at all times, including when accessing the EVD to collect routine biweekly CSF samples. During CSF draws, a sterile field was established, and the appropriate access port was prepped with chlorhexidine. Typically, up to four collection tubes were drawn by passive flow for analysis. Aspiration of CSF, when needed, was performed only by an appropriately trained physician.

#### Antibiotic Use

Periprocedural prophylactic antibiotics are not administered before EVD placement at our institution. Moreover, antibiotic-impregnated catheters were not inserted for external ventricular drainage.

#### VAI Reporting

A standardized reporting methodology was instituted in accordance with CDC reporting guidelines for central line infections and ventilator-associated pneumonia [10] to facilitate our institution's long-term quality control evaluations and multi-institutional data collection. In accordance with these standards, the rate of VAI was calculated as a function of the total number of EVD device days and normalized per 1,000 days as follows:

$$\text{Rate of VAI} = \frac{\text{No. of VAIs}}{\text{No. of EVD device days}} \times 1000$$

#### Statistical Analysis

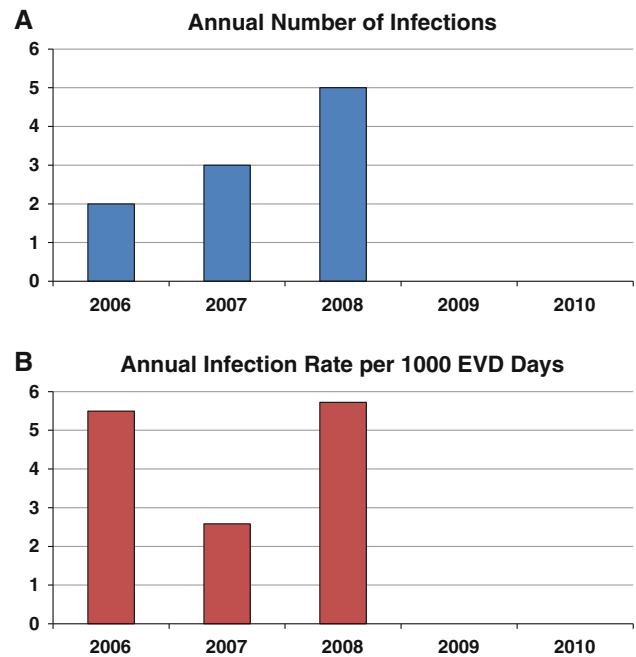
Because infection is a categorical (binary) variable, chi square, and logistic regression methods were performed to study its determinants. All statistical analysis was carried out using SAS, Version 9.3 (SAS Institute, Cary, and NC).

#### Results

During the 4-year study period (2006–2010) when 498 patients underwent insertion of an EVD catheter in our neurosurgical ICU, ten patients developed VAIs as defined by our study criteria (Table 1). From a total of 4,673 EVD days, the average duration of EVD placement was 9.4 days and the infection rate was 2.14 per 1,000 ventriculostomy days. However, our yearly infection rates differed, ranging from 0 to 5.72 (Fig. 1). In traditional terms, the infection rate was 2.0 % per patient who underwent ventriculostomy

**Table 1** Annual incidence of infection

Year	# of EVDs	# of EVD days	# of infections	Infection rate per 1,000 EVD days
2006	27	364	2	5.49
2007	125	1162	3	2.58
2008	135	874	5	5.72
2009	132	1125	0	0.00
2010	79	1148	0	0.00
Cum. totals	498	4673	10	2.14



**Fig. 1** Annual number of infections (a) and infection rate (b) normalized per 1,000 EVD device days in accordance with CDC guidelines for device-associated infections

placement during the four years, with no infections recorded in 2009 or 2010.

Among the ten patients with VAIs, the underlying pathological processes that resulted in invasive intracranial monitoring were 5 (50 %) subarachnoid hemorrhage, 1 (10 %) arteriovenous malformation, and 4 (40 %) intraparenchymal or intraventricular hemorrhage (Table 2). From the 14 isolates cultured in these patients, infectious etiologies included methicillin resistant *Staphylococcus aureus* ( $n = 1$ ), methicillin sensitive *Staphylococcus aureus* ( $n = 1$ ), *Pseudomonas aeruginosa* ( $n = 3$ ), coagulase-negative *Staphylococcus* ( $n = 5$ ), *Enterobacter cloacae* ( $n = 1$ ), *Klebsiella pneumonia* ( $n = 1$ ),  $\beta$ -hemolytic *Streptococcus* ( $n = 1$ ), and *Acinetobacter baumannii* ( $n = 1$ ) (Table 2). Given the few total infections, there was no statistically significant association between the causative

**Table 2** Characteristics of patients with ventriculostomy-associated infections

Patient	Reason for EVD	Date (Month/Year)	Organism	CSF glucose	Serum glucose
1	SAH <sup>a</sup>	10/2006	MRSA <i>Pseudomonas aeruginosa</i>	11	101
2	SAH	11/2006	MSSA Subarachnoid hemorrhage	80	109
3	SAH	3/2007	CNS <sup>c</sup>	60	97
4	AVM <sup>b</sup> /SAH	5/2007	CNS	80	107
5	IPH <sup>c</sup>	9/2007	<i>Pseudomonas aeruginosa</i>	88	140
6	IPH/IVH <sup>d</sup>	9/2008	CNS	33	84
7	IPH	9/2008	CNS <i>Enterobacter cloacae</i>	71	143
8	IPH/IVH	9/2008	<i>Klebsiella pneumonia</i> $\beta$ -hemolytic <i>Streptococci</i>	<10	136
9	SAH	10/2008	<i>Pseudomonas aeruginosa</i>	66	173
10	SAH	11/2008	CNS	82	112

<sup>a</sup> Subarachnoid hemorrhage; <sup>b</sup>Arteriovenous malformation; <sup>c</sup>Intraparenchymal hemorrhage; <sup>d</sup>Intraventricular hemorrhage; and <sup>e</sup>Coagulase-negative *Streptococci*

organism of VAI and the underlying pathological process for which ventriculostomy placement was used.

Finally, in an attempt to assess for possible predictors of VAI at the time of EVD placement, analysis was performed for CSF collected at the time of ventriculostomy. Notably, CSF glucose was isolated as a possible determinant of infection, while four other sample values—serum glucose, CSF protein, CSF white blood cells (WBC), and CSF red blood cells (RBC)—demonstrated no statistically significant predictive capacity. CSF glucose was inversely correlated with the rate of infection, with an odds ratio of predicting infection of 0.97 ( $p = 0.049$ ; 95 % CI 0.95–1.00) when treated as a continuous variable and after adjustment for total RBCs. Thus, for each 1 mg/dL decrease in CSF glucose, the odds of infection increase by 3 %. In contrast, the odds ratios for CSF, RBC, and WBC adjusted for RBC are 1.00 ( $p = 0.25$ ) and 0.12 ( $p = 0.72$ ), respectively. When dichotomized at 50 mg/dL, CSF glucose demonstrated a strong trend toward significance with an odds ratio of 4.83 ( $p = 0.054$ , 95 % CI 0.97–24.0). This enhanced risk was further supported, when CSF glucose was normalized to serum glucose. Patients in whom CSF glucose was less than 50 % of serum glucose were significantly more likely to develop an infection following ventriculostomy (odds ratio = 4.87,  $p = 0.021$ , 95 % CI 1.26–18.75).

## Discussion

The lack of a standardized definition for VAI has led to a wide range of reported incidence. Although this shortcoming has been well described [4], poor reporting standards have further degraded the capacity to diagnose, track, prevent, and appropriately treat VAI in affected patients. By refining the definition of VAI and adopting a CDC reporting format based on device-related infection

guidelines, our prospective study following infection rates after EVD placement effectively addresses the shortcomings created by both the lack of a uniform definition and the varying rates of complication incidence that ensued. With these reforms and a standardized nursing protocol for ventriculostomy patients in the neurosurgical ICU, our institutional 2.0 % rate of infection (or 2.14 per 1,000 ventriculostomy days) compares favorably with rates reported in the literature that range from 2.3 to 24 % [4, 7–9]. These data support previous studies documenting that the application of specific EVD placement and care protocols can help to reduce overall infection rates [14, 15]. Notably, our proposed protocol differs because it specifically excludes the routine use of both antibiotic-impregnated catheters and prophylactic antibiotics during the periods of ventriculostomy insertion or sampling access.

Our refinement of the definition of VAI previously proposed by Lozier et al. [4] consisted of both a positive CSF culture in a patient with a ventriculostomy catheter and a fever ( $>101.5^{\circ}$  F) and/or CSF glucose level, either  $<50$  mg/dL or  $<50$  % of a serum glucose level drawn within 24 h of the CSF glucose sampling. Our reporting guidelines conform to those issued by the CDC for central lines, ventilator-associated pneumonias, and dialysis-related infections [10]. Many reports inconsistently describe rates of infection per EVD or per patient, which can minimize the role of common confounders, including prolonged catheter use [7]. Normalization of institutional rates by EVD device days as initially proposed by Scheithauer et al. [11] and specifically outlined here will allow individual centers to monitor both intra- and inter-institutional performance and to develop appropriate quality control measures.

Reports of systematic application of antibiotics in ventriculostomy patients using different approaches [2, 9] have

failed in lowering infection rates. Given the significant implications of evolving anti-microbial resistance for modern medicine, our current recommendations for EVD care exclude the routine use of antibiotics. However, we do recommend that patients with EVDs be placed in the intensive care setting where nursing ratios are favorable and specialized EVD care can be administered. In addition, our low infection rates with the use of traditional ventriculostomy catheters in a setting with appropriate care does not warrant the use of antibiotic-impregnated catheters, signaling a potential avenue for cost-savings in patient care.

In our analyses, we noted a statistically significant correlation between CSF glucose levels drawn immediately after placement of the ventriculostomy catheter that were <50 % of serum glucose and subsequent risk of infection. As CSF glucose is typically reduced during active bacterial infection, the finding of low glucose levels at the time of EVD placement may be indicative of a preexisting central nervous system infection in these patients. However, a similar association was not found with either CSF pleocytosis or protein levels as would have been expected in the setting of an incumbent infection. Of note, 18 uninfected patients also had CSF glucose <50 mg/dL. This finding suggests that while the absolute glucose value is not specific as a determinant for infection, it may help to identify the subset of the patients with the highest risk of developing infection at the time of ventriculostomy placement. Additional investigation is required to further evaluate the predictive value of CSF glucose in this setting, and whether these patients would uniquely benefit from prophylactic antibiotics or exchange to antibiotic-impregnated catheters.

Although VAI is uncommon as evidenced by our series' incidence of 2.14 per 1,000 ventriculostomy days, the results of such a complication are devastating neurologic morbidity and often long-term sequelae. With a refined definition of VAI and standardized CDC report derived from well-established guidelines for other catheter-related infections, our findings propose a benchmark measure of infection to be less than or equal to 5 per 1,000 device days. During 2009 and 2010, a period encompassing over 200 EVDs and approximately 2300 EVD device days, no VAIs were recorded at our institution. Thus, we recommend strict adherence to EVD care protocols rather than the routine use of prophylactic antibiotics or antibiotic-impregnated catheters.

**Conflict of interest** The authors declare that no financial, personal, or professional competing interests exist

## References

1. Arabi Y, Memish ZA, Balkhy HH, et al. Ventriculostomy-associated infections: incidence and risk factors. *Am J Infect Control*. 2005;33:137–43.
2. Alleyne CH Jr, Hassan M, Zabramski JM. The efficacy and cost of prophylactic and perioperative antibiotics in patients with external ventricular drains. *Neurosurgery*. 2000;47:1124–9.
3. Clark WC, Muhlbauer MS, Lowrey R, et al. Complications of intracranial pressure monitoring in trauma patients. *Neurosurgery*. 1989;25:20–4.
4. Lozier AP, Sciacca RR, Romagnoli MF, Connolly ES Jr. Ventriculostomy-related infections: a critical review of the literature. *Neurosurgery*. 2002;51:170–82.
5. Lyke KE, Obasanjo OO, Williams MA, et al. Ventriculitis complicating use of intraventricular catheters in adult neurosurgical patients. *Clin Infect Dis*. 2001;33:2028–33.
6. Bota DP, Lefranc F, Vilallobos HR, et al. Ventriculostomy-related infections in critically ill patients: a 6-year experience. *J Neurosurg*. 2005;103:468–72.
7. Park P, Garton HJ, Kocan MJ, Thompson BG. Risk of infection with prolonged ventricular catheterization. *Neurosurgery*. 2004; 55:594–601.
8. Kim JH, Desai NS, Ricci J, et al. Factors contributing to ventriculostomy infection. *World Neurosurg*. 2012;77:135–40.
9. Pople I, Poon W, Assaker R, et al. Comparison of infection rate with the use of antibiotic-impregnated versus standard extraventricular drainage devices: a prospective, randomized controlled trial. *Neurosurgery*. 2012;71:6–13.
10. Edwards JR, Peterson KD, Mu Y, et al. National Healthcare Safety Network (NHSN) report: data summary for 2006 through 2008, issued December 2009. *Am J Infect Control*. 2009; 37:783–805.
11. Scheithauer S, Burgel U, Ryang YM, et al. Prospective surveillance of drain associated meningitis/ventriculitis in a neurosurgery and neurological intensive care unit. *J Neurol Neurosurg Psychiatry*. 2009;80:1381–5.
12. Mayhall CG, Archer NH, Lamb VA, et al. Ventriculostomy-related infections. A prospective epidemiologic study. *N Engl J Med*. 1984;310:553–9.
13. Sundbarg G, Nordstrom CH, Soderstrom S. Complications due to prolonged ventricular fluid pressure recording. *Br J Neurosurg*. 1988;2:485–95.
14. Dasic D, Hanna SJ, Bojanic S, Kerr RS. External ventricular drain infection: the effect of a strict protocol on infection rates and a review of the literature. *Br J Neurosurg*. 2006;20:296–300.
15. Flint AC, Rao VA, Renda NC, et al. A simple protocol to prevent external ventricular drain infections. *Neurosurgery*. 2013;72: 993–9.