

Central-Line-Associated Bloodstream Infection: Comprehensive, Data-Driven Prevention

*James Davis, BSN, RN, CCRN, CIC
Senior Infection Prevention Analyst
Pennsylvania Patient Safety Authority*

ABSTRACT

Central venous catheters provide necessary vascular access; however, their use places patients at risk for infection. Central-line-associated bloodstream infection occurs when there are lapses in care in insertion and maintenance. It is essential that a comprehensive infection prevention program be data driven. During calendar year 2010, of Pennsylvania acute care facilities that had submitted central venous catheter insertion dates to the National Healthcare Safety Network, 71.7% reported that central-line-associated bloodstream infections occurred more than five days after insertion. Biofilm formation in the internal lumen and subsequent late onset of bacteremia (after five days) may signify failure in central line maintenance practices. Pennsylvania's data suggests that health-care facilities need to focus greater attention on catheter maintenance, in addition to complying with best practices during insertion. (*Pa Patient Saf Advis* 2011 Sep;8[3]:100-4.)

INTRODUCTION

Central venous catheters (CVC) provide necessary access to the bloodstream; however, their use places patients at risk for central-line-associated bloodstream infection (CLABSI).¹ The two phases, insertion and maintenance, of CVC life and associated CLABSI prevention strategies may challenge infection preventionists when assigning resources to the CVC phase that is causing suboptimal CLABSI rates. A survey of Society of Healthcare Epidemiology of America (SHEA) members found that hospital epidemiology and infection control departments experienced an increase in responsibilities and scope, while in many instances resources were below levels recommended by expert panels in the peer-reviewed literature.² Designing systems for preventing CLABSI and auditing compliance with best practices can be daunting without appropriate resources. Data interpretation can help in the design of effective CLABSI prevention programs and prove to be an ally when resources are not available, are not allocated appropriately, or are underutilized. Pennsylvania Patient Safety Authority analysts have captured data that may help determine whether an institution should focus resources on a specific phase of CVC life to prevent CLABSI.

BACKGROUND

There are two types of CVC: short-term and long-term. Short-term catheters are commonly used in acute care or emergent settings and dwell for 10 days or less. Long-term catheters typically remain in place for more than 10 days.³ Long-term catheters usually contain implanted cuffs and include devices like ports, making them more complex than short-term catheters. Peripherally inserted central catheters (PICCs) have traditionally been considered long-term devices but are becoming more prevalent in acute care settings. Data collected from outpatient and inpatient studies suggests that the risk for infection associated with PICC use is similar to that for cuffed or tunneled catheter use.³

The common risk factor for infection among CVC types is catheter dwell time; the longer the dwell time and the greater the use, the higher the risk for infection. Mermel and Maki analyzed the pooled data from four prospective studies that noted the outcomes of 988 Swan-Ganz catheters and concluded that Swan-Ganz catheters, because of infection risk, should be short-term lines, used for no longer than four days except in extenuating circumstances.⁴

Microbes can be introduced into the patient from the patient's skin, the environment, or healthcare workers' hands during initial CVC insertion or at any point during use of the CVC. Introduction of organisms into or onto the CVC can precipitate biofilm formation. Microbial biofilm develops when microorganisms irreversibly adhere to and form a structural matrix on a surface.⁵ CVC surfaces are at risk for biofilm formation wherever they are in a resource-sustainable environment. CVC surfaces come in contact with such an environment when the patient's blood contacts the exterior surface (extraluminal) or the interior channel (intraluminal) of the catheter that is used to administer fluids, medications, blood, or other intravascular therapies. Bloodstream infections related to long-term CVC use are almost always a result of intraluminal biofilm development.^{6,7} Examining how, when, and where biofilm forms can provide insight into CLABSI prevention strategies at both phases of CVC life.

CLABSI PREVENTION: INSERTION AND MAINTENANCE

CLABSI may occur as a result of lapses in care in insertion or maintenance; therefore infection prevention strategies focus on these areas. Lapses in care surrounding insertion happen over a short period, from seconds to hours, setting up an environment



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for inoculation with bacteria and the potential for conditions that aid extraluminal biofilm formation.⁵ Opportunities for failure in the maintenance phase are numerous and have days to months to precipitate intraluminal-sourced CLABSI.^{6,7} For example, in the pediatric population, McKee alludes to maintenance failures by stating that improving practices for central line insertion leads to a reduction in CLABSI, but not its elimination.⁸ If proper insertion is the foundation of a strong CLABSI prevention program, then solid maintenance practices are essential to protect patients from infection.

Insertion

The intensive care unit (ICU) project of the Michigan Health and Hospital Association (MHA) Keystone Center for Patient Safety and Quality, funded by the Agency for Healthcare Research and Quality (AHRQ), was able to achieve impressive results with relatively simple interventions. The interventions included the use of an insertion checklist, hand hygiene, chlorhexidine for skin preparation, appropriate site selection, maximal barriers, daily review of line necessity, and a maintenance protocol. During the project, participants were able to maintain very low infection rates for extended periods.⁹ Many CLABSI prevention programs have been modeled after this study, using the insertion protocol, insertion checklist, and daily goal sheets. These selected interventions are relatively inexpensive and simple to implement, but they focus on CVC insertion. Many regulatory bodies now require compliance with these practices, heavily weighting the insertion phase of CVC care. Since January 2010, the Joint Commission has required hospitals to use a standardized supply kit or cart, a catheter checklist, and a standard protocol for insertion.¹⁰ These insertion requirements are the foundation of CLABSI prevention but do not constitute a complete prevention program.

Maintenance

Insertion is a quick procedure performed by a small group of providers that must adhere to a proven set of best practices. Maintenance of the line occurs over many hours to months and involves a host of individuals (e.g., nurses, physicians, caregivers, patients, and families), all of whom have a hand in causing or preventing the development of CLABSI. Practices that limit the introduction of organisms into the CVC have been a focus of CLABSI prevention, specifically when the catheter is accessed by the healthcare professional. Failure to disinfect hubs and caps, for example, can lead to the development of intraluminal biofilm, which may lead to infection. Microbial biofilms on the intraluminal surface originate from microorganisms transported through contaminated injection ports, needleless connectors, stopcocks, and catheter hubs.¹¹ The CVC hub, needleless cap, and intraluminal surfaces of CVCs are a potential source of CLABSI.⁷ Safdar and Maki report that after changing CVC insertion protocols in an ICU to chlorhexidine (CHG) skin antisepsis and a CHG dressing, CLABSI shifted from extraluminal sources to intraluminal sources.¹² Extraluminal contamination can be minimized if staff performs adequate skin antisepsis and applies an occlusive dressing including a CHG delivery method (sponge or other product).

Maintenance of the CVC is essential for building a program that is resistant to the late development of CLABSI. Opportunities for intraluminal contamination are more frequent after the line is in use. During a root-cause analysis conducted to identify sources of CLABSI in Canadian pediatric ICUs, investigators found several causal factors, including positive pressure needleless caps on PICC s and an excessive number of ports on infusion systems. In addition, they noticed inconsistent practice, line necessity based on limited alternatives for intravenous access, and

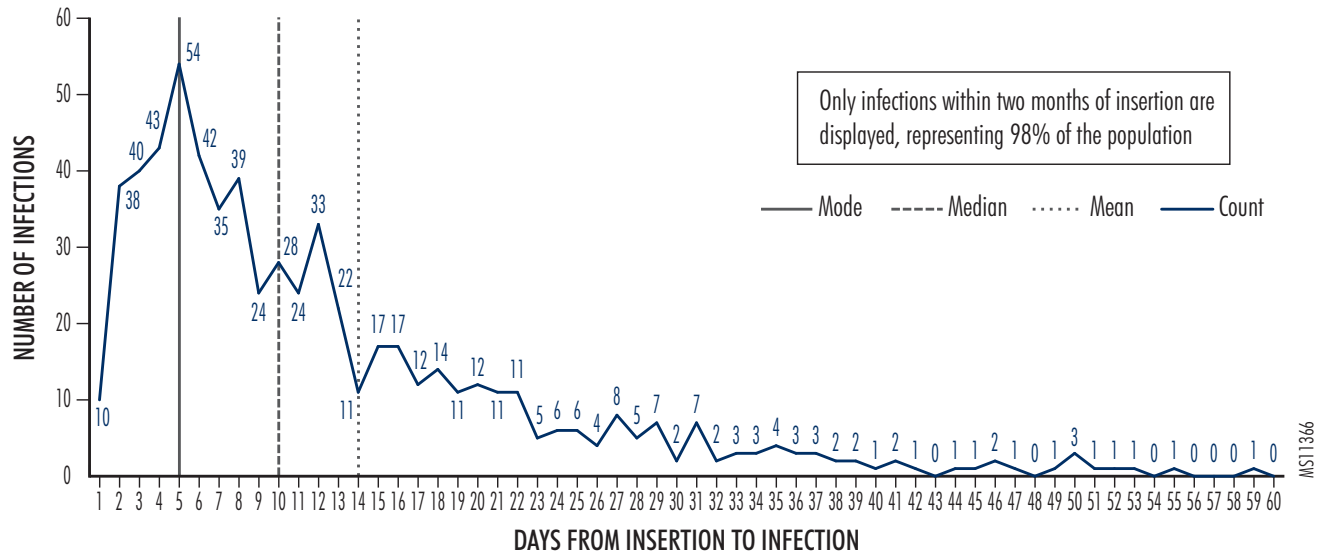
inadequate monitoring, all of which contributed to development of CLABSI.¹³ “There are many procedures, many steps, and many personnel that are involved in the placement, care and maintenance of central venous catheters,”¹⁴ said Neil Fishman, MD, past president of SHEA.

How healthcare providers interact with the CVC has direct impact on care failures experienced by the patient. For example if a caregiver does not thoroughly disinfect the hub and needleless connector of a CVC with an antiseptic, organisms could be injected into the CVC and precipitate the formation of biofilm.¹⁵ Ryder notes that the internal lumen can be the primary source of bacteremia in short-term catheters as early as day 5 postinsertion.⁶ Causal or preventative opportunities begin the minute the decision is made to place a central line in a patient.

METHODS

Using fields readily available in the NHSN data analytics function tab, Authority analysts queried the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) database to determine the date of infection event from the documented date of insertion for CVCs in Pennsylvania's acute care facilities from January through December 2010, as of March 22, 2011. Date of CVC insertion and date of infection event were the two fields chosen to isolate data related to the determination of early- versus late-onset CLABSI. It is important to note that the date of insertion field in the NHSN reporting system is not a mandatory field. Analysts excluded events when insertion-to-event times were less than one day. Analysts also excluded events with blank fields, missing data, or dates in reverse order. The final sample size included 653 events. Authority analysts have chosen a cut point after day 5 that would most likely indicate intraluminal biofilm formation caused by maintenance failures.⁶

Figure 1. Time Distribution of CLABSI: Pennsylvania NHSN Facilities 2010



RESULTS

According to Authority analysis of 2010 event reports, the majority of CLABSIs occurring in Pennsylvania acute care facilities have been late in onset: of the 653 central-line-related infection events reported to NHSN in 2010 by Pennsylvania facilities, 468 (71.7%) occurred after day five (see Figure 1). Pennsylvania facilities may need to direct their resources toward maintaining CVCs.

Figure 2 represents 104 Pennsylvania facilities that reported data for both CLABSI and time of CVC insertion in 2010. Individual facilities were listed based on total number of infections, then numbered and deidentified. This distribution of infection implicates maintenance as the phase in which CLABSI most likely is developed.

DISCUSSION

Data points for catheter dwell time to infection event, combined with published time lines on pathogenesis of intraluminal

versus extraluminal biofilm formation, can help allocate resources that focus on corrective actions. Data-driven decisions, data-based interventions, and corrective actions can be directed at the specific time at which CLABSI develops. Utilizing time-to-infection data will have a significant effect on a facility’s CLABSI prevention program, especially if resources are scarce. If there are more breaches in compliance with insertion practices, the incidence of infection will increase early in the life of the CVC. If infections are occurring later in the life of the CVC, breaches in the care and maintenance of CVCs may be implicated.

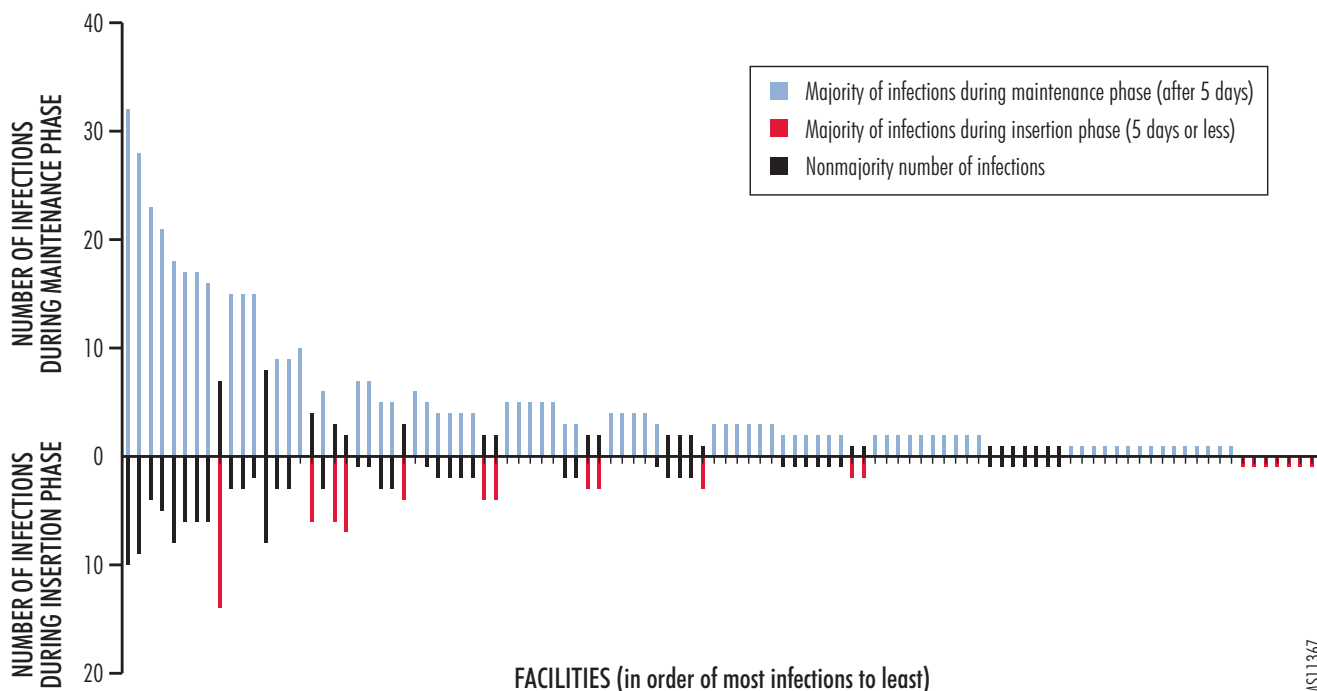
The MHA project allocated significant resources and funds to a CLABSI prevention infrastructure (AHRQ financially supported the majority of the project). In addition to the recommended evidence-based procedures for CVC insertion and daily goal sheets, the MHA study implemented a comprehensive program that addressed a culture of safety in the units where data was collected. Pronovost et al.

note the importance of an infrastructure used to monitor CLABSI rates and the use of a staff of hospital-based infection preventionists for this study. They note that similar infrastructure does not exist for most other issues related to patient safety.⁹ Despite the possibility of infrastructure differences, each facility in Pennsylvania can use its own data and determine which way it believes the scale is tipped. If the majority of infections occur before or on day 5, insertion bundle compliance may be worth auditing more closely; conversely, if the majority of infections occur after five days postinsertion, perhaps care and maintenance practices should be monitored. When a facility knows where to allocate resources, infection prevention measures can be implemented to effectively reduce infection rates.

The following links from CDC provide information on isolating facility-specific data from NHSN for analysis:

- Quick Tips: Run and Modify Output <http://www.cdc.gov/nhsn/PDFs/AnalysisBasics.pdf>

Figure 2. Time to CLABSI as Reported by Pennsylvania NHSN Facilities in 2010: Insertion versus Maintenance



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- NHSN Analysis: Advanced Features & Terminology http://www.cdc.gov/nhsn/wc_Analysis_Advan_Features.html
 - NHSN Analysis: Advanced Features & Terminology: Training Session for NHSN Hospitals, December 19, 2006 http://www.cdc.gov/nhsn/PDFs/slides/NHSN_trainingDec19PAandMAAnalysis.pdf
- To help Pennsylvania facilities assess their overall CLABSI prevention programs, the Authority maintains a CLABSI

prevention toolkit, available at <http://patientsafetyauthority.org/EducationalTools/PatientSafetyTools/clabsi/Pages/home.aspx>.

CONCLUSION

The CLABSI data presented here by Authority analysts is a glimpse into the meaningful use of event data collected by dedicated Pennsylvania infection preventionists and others. Given the available sample size, the Authority believes that facilities are putting time-to-infection data to use. Infection preventionists have

invested a great deal of effort uploading infection-related event data. All infection types can benefit from like analysis and interpretation. Event reporting is mandatory, and reported data is a powerful assessment tool that needs to be continually used by facility-level infection preventionists and all disciplines for the safety of Pennsylvania patients. The effectiveness of intervention and applied resources is compelling. Pennsylvania's data suggests that healthcare facilities need to focus greater attention on catheter maintenance, in addition to complying with best practices during insertion.

NOTES

1. O'Grady NP, Alexander M, Burns LA, et al. Guidelines for the prevention of intravascular catheter-related infections, 2011 [online]. 2011 Jun [cited 2011 Jun 6]. Available from Internet: <http://www.cdc.gov/hicpac/pdf/guidelines/bsi-guidelines-2011.pdf>.
2. Wright SB, Ostrowsky B, Fishman N, et al. Expanding roles of healthcare epidemiology and infection control in spite of limited resources and compensation. *Infect Control Hosp Epidemiol* 2010 Feb;31(2):127-32.
3. Crnich CJ, Maki DG. The promise of novel technology for the prevention of intravascular device-related bloodstream infection. II. Long-term devices. *Clin Infect Dis* 2002 May 15;34(10):1362-8.
4. Mermel LA, Maki DG. Infectious complications of Swan-Ganz pulmonary artery catheters. Pathogenesis, epidemiology, prevention, and management. *Am J Respir Crit Care Med* 1994 Apr;149(4 Pt 1):1020-36.
5. Donlan RM. Biofilms and device-associated infections. *Emerg Infect Dis* 2001 Mar-Apr;7(2): 277-81.
6. Ryder M, Gunther RA, Breznock EM, et al. The effect of chlorhexidine antimicrobial coating on the reduction of intraluminal biofilm formation in a clinically simulated ovine model (pilot study). Abstract at: SHEA 2011 Annual Scientific Meeting; 2011 April.
7. Ryder MA. Catheter-related infections: it's all about biofilm [online]. *Top Adv Nurs* 2005 Aug 18 [cited 2011 Mar 23]. Available from Internet: <http://www.medscape.com/viewarticle/508109>.
8. McKee C, Berkowitz I, Cosgrove SE, et al. Reduction of catheter-associated bloodstream infections in pediatric patients: experimentation and reality. *Pediatr Crit Care Med* 2008 Jan;9(1):40-6.
9. Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 2006 Dec 28;355(26):2725-32
10. Joint Commission. National Patient Safety Goals [2008 Goal 7:07.04.01 online]. [cited 2011 Mar 30]. Available from Internet: http://jointcommission-lms.org/1900_00_HAI_NPSG_7/player.html.
11. Ryder M. Improve CRBSI prevention: target intraluminal risks [website]. [cited 2011 Jul 21]. Available from Internet: <http://www.executivehm.com/article/Improve-CRBSI-Prevention-Target-Intraluminal-Risks>.
12. Safdar N, Maki DG. The pathogenesis of catheter-related bloodstream infection with noncuffed short-term central venous catheters. *Intensive Care Med* 2004 Jan;30(1)62-7.
13. Northway T, Mawdsley C. The Canadian ICU collaborative: sustaining the gains: a lesson in humility. *Dynamics* 2009 Fall; 20(3):23-7.
14. Harutyunyan R. Drawing road map for CLABSI elimination [online]. *Emax-Health* 2009 Mar 21 [cited 2011 Mar 31]. Available from Internet: <http://www.emaxhealth.com/2/39/30023/drawing-road-map-clabsi-elimination.html>.
15. Ryder M, Schaudinn C, Gorur A. Microscopic evaluation of microbial colonization on needleless connectors. Abstract at: APIC 2008 Annual Meeting; 2008.

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