Guidelines for the Prevention of Intravascular Catheter-related Infections: Recommendations Relevant to Interventional Radiology for Venous Catheter Placement and Maintenance

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ABBREVIATIONS

BSI = bloodstream infection, CDC = Centers for Disease Control, CLABSI = central line–associated bloodstream infection, CRBSI = catheter-related bloodstream infection, CVC = central venous catheter, ICU = intensive care unit, MSB = maximum sterile barrier, PICC = peripherally inserted central catheter

INTRODUCTION

In the United States, 80,000 catheter-related bloodstream infections (CRBSIs) occur in intensive care units (ICUs) each year (1), and a total of 250,000 cases of CRBSIs have been estimated to occur annually if entire hospitals are assessed (2). In the ICU, these infections independently increase hospital costs and length of stay (3), but have not generally been shown to independently increase mortality.

The second edition of the Centers for Disease Control (CDC) Guidelines for the Prevention of Intravascular Catheter-related Infections was published on August 9, 2002, in the Reports and Recommendations series of the Morbidity and Mortality Weekly Report (4), and replaced the original guideline published in 1996. The goal was to provide evidence-based recommendations for preventing catheter-related infections. Selected recommendations from the 2002 guideline relevant to interventional radiology were excerpted as a Society of Interventional Radiology (SIR) guideline published in the *Journal of Vascular and Interventional Radiology* in 2003 (5,6).

Major areas of emphasis in the 2002 CDC Guidelines included (i) educating and training health care providers who insert and maintain catheters, (ii) using maximum sterile barrier (MSB) precautions during central venous catheter (CVC) insertion, (iii) using a 2% chlorhexidine preparation for skin antisepsis, (iv) avoiding routine replacement of CVCs as a strategy to prevention of infection, and (v) using antiseptic/antibiotic agent–impregnated short-term CVCs and chlorhexidine-impregnated sponge dressings if the rate of infection is high despite adherence to other strategies (ie, education and training, MSB precautions, and 2% chlorhexidine for skin antisepsis).

Unfortunately, implementation of evidence-based CRBSI preventive practices in US hospitals has been suboptimal (3). In a national survey conducted in March 2005 of more than 700 US hospitals, approximately one quarter of hospitals indicated that (i) MSB precautions during central catheter insertion and (ii) chlorhexidine gluconate as site disinfectant, two practices widely recommended in the 2002 guidelines, were not being used routinely (7). Approximately 15% of US hospitals reported routinely changing CVCs to prevent infection despite evidence that this practice should no longer be used (3,7).

The 2002 CDC guideline has now been revised and updated. The new document, published in 2011 (8), was prepared by a working group comprising members from professional organizations representing the disciplines of critical care medicine, infectious diseases, health care infection control, surgery, anesthesiology, interventional radiology, pulmonary medicine, pediatric medicine, and nursing. The working group was led by the Society of Critical Care Medicine, in collaboration with the Infectious Disease Society of America, Society for Healthcare Epidemiology of America, Surgical Infection Society, American College of Chest Physicians, American Thoracic Society, American Society of Critical Care Anesthesiologists, Association for Professionals in Infection Control and Epidemiology, Infusion Nurses Society, Oncology Nursing Society, American Society for Parenteral and Enteral Nutrition, the Society of Interventional Radiology, American Academy of Pediatrics, Pediatric Infectious Diseases Society, and the Healthcare Infection Control Practices Advisory Committee of the CDC.

The 83-page electronic version of the 2011 CDC guideline is available online without charge (http://www.cdc.gov/hicpac/pdf/guidelines/bsi-guidelines-2011.pdf). Major areas of emphasis in the 2011 guideline include (i) educating and training health care personnel who insert and maintain catheters, (ii) using MSB precautions during CVC insertion, (iii) using a greater than 0.5% chlorhexidine skin preparation with alcohol for antisepsis, (iv) avoiding routine replacement of CVCs as a strategy to prevent infection, and (v) using antiseptic/antibiotic agent–impregnated short-term CVCs and chlorhexidine-impregnated sponge dressings if the rate of infection is not decreasing despite adherence to other strategies (ie, education and training, MSB precautions, and > 0.5% chlorhexidine preparations with alcohol for skin antisepsis).

The CDC guideline is lengthy and includes recommendations regarding hand hygiene, peripheral venous catheters, umbilical catheters,

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The first version of this article appeared in J Vasc Interv Radiol 2003; 14(suppl):S355–S358.

N.P.O. is an employee of the National Institutes of Health. The other author has not identified a conflict of interest. The opinions expressed herein are those of the authors and do not necessarily reflect those of the National Institutes of Health or the Department of Health and Human Services.

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Published by Elsevier Inc. on behalf of SIR.

J Vasc Interv Radiol 2012; 23:997–1007

http://dx.doi.org/10.1016/j.jvir.2012.04.023

peripheral arterial catheters, and replacement of administration sets and needleless intravascular catheter systems. These topics are not reviewed here. Portions of the new guideline are of particular interest to interventional radiologists, particularly those dealing with CVCs, peripherally inserted central catheters (PICCs), and hemodialysis catheters. This revised SIR guideline contains selected recommendations from the 2011 CDC guideline, presented verbatim, along with selected supporting data, background information, and references.

Definitions

Catheter-related Bloodstream Infection. Catheter-related bloodstream infection is a clinical definition used when diagnosing and treating patients. It requires specific laboratory testing to identify more thoroughly the catheter as the source of the bloodstream infection (BSI). It is often problematic to precisely establish if a BSI is a CRBSI as a result of the clinical needs of the patient (the catheter is not always removed), limited availability of microbiologic methods (many laboratories do not use quantitative blood cultures or differential time to positivity), and procedural compliance by direct care personnel (labeling must be accurate).

Central Line–associated BSI. "Central line–associated BSI" (CLABSI) is a term used by the CDC's National Healthcare Safety Network. A CLABSI is a primary BSI in a patient who had a central catheter within the 48-hour period before the development of the BSI, and is not related to an infection at another site. However, as some BSIs are secondary to other sources (other than the central catheter) that may not be easily recognized (eg, pancreatitis, mucositis), the CLABSI surveillance definition may overestimate the true incidence of CRBSI.

Midline Catheter. A midline catheter is a catheter inserted via the antecubital fossa into the proximal basilic or cephalic veins that does not enter the central veins.

Microbiology

The most commonly reported causative pathogens remain coagulase-negative staphylococci, *Staphylococcus aureus*, enterococci, and *Candida* species (9). Gram-negative bacilli accounted for 19% and 21% of CLABSIs reported to the CDC (10) and the Surveillance and Control of Pathogens of Epidemiological Importance database, respectively (9).

For all common pathogens causing CLABSIs, antimicrobial resistance is a problem, particularly in ICUs. Although methicillin-resistant *S. aureus* now account for more than 50% of all *S. aureus* isolates obtained in ICUs, the incidence of methicillin-resistant *S. aureus* CLABSIs has decreased in recent years, perhaps as a result of prevention efforts. For Gram-negative rods, antimicrobial resistance to third-generation cephalosporins among *Klebsiella pneumoniae* and *Escherichia coli* has increased significantly, as has imipenem and ceftazidime resistance among *Pseudomonas aeruginosa* (10). *Candida* species are increasingly noted to be fluconazole-resistant.

Pathogenesis

There are four recognized routes for contamination of catheters: (i) migration of skin organisms at the insertion site into the cutaneous catheter tract and along the surface of the catheter with colonization of the catheter tip (the most common route of infection for short-term catheters) (11,12), (ii) direct contamination of the catheter or catheter hub by contact with hands or contaminated fluids or devices (13), (iii) hematogenous seeding from another focus of infection (less common) (14), and (iv) infusate contamination (rare) (15).

Important pathogenic determinants of CRBSI are (i) characteristics of the device material; (ii) the host factors, consisting of protein adhesions such as fibrin and fibronectin, that form a sheath around the catheter (16); and (iii) the intrinsic virulence factors of the infecting organism, including the extracellular polymeric substance produced by the adherent organisms (17).

As a result of fibrin sheath formation, silastic catheters are associated with higher risk of catheter infections than polyurethane catheters (16). Biofilm formation by *Candida albicans* occurs more readily on silicone elastomer catheter surfaces than on polyurethane catheters (18). Modification of the biomaterial surface properties has been shown to influence the ability of *C. albicans* to form biofilm. Some catheter materials have surface irregularities that enhance the microbial adherence of certain species (eg, *Staphylococcus epidermidis* and *C. albicans*) (18). Catheters made of these materials are particularly vulnerable to microbial colonization and subsequent infection. Additionally, certain catheter materials are more thrombogenic than others, a characteristic that might also predispose to catheter colonization and infection (19). This association has led to emphasis on preventing catheter-related thrombus as an additional mechanism for reducing CRBSI (20).

Host factors are also important in the pathogenesis of CRBSI, as they affect the adherence properties of a given microorganism. For example, *S. aureus* can adhere to host proteins (eg, fibrinogen, fibronectin) commonly present on catheters by expressing clumping factors that bind to the protein adhesins (16,19,21). Microbial adherence is also enhanced through the production, by microbial organisms such as coagulase-negative staphylococci (22), *S. aureus* (23), *P. aeruginosa* (24), and *Candida* species (25), of an extracellular polymeric substance that consists mostly of an exopolysaccharide that forms a microbial biofilm layer. This biofilm matrix is enriched by divalent metallic cations, such as calcium, magnesium, and iron, enabling microbial organisms to embed themselves (26). These biofilms potentiate the pathogenicity of various microbes by allowing them to withstand host defense mechanisms (eg, acting as a barrier to engulfment and killing by polymorphonuclear leukocytes) or by making them less susceptible to antimicrobial agents (eg, forming a matrix that binds antimicrobial agents before their contact with the organism cell wall or providing for a population of metabolically quiescent, antimicrobial tolerant "persister" cells) (22,27). In the presence of dextrose-containing fluids, some *Candida* species produce slime similar to that of their bacterial counterparts, potentially explaining the increased proportion of BSIs caused by fungal pathogens among patients receiving parenteral nutrition fluids (28).

CLASSIFICATION OF RECOMMENDATIONS

The 2011 CDC guideline contains a Summary of Recommendations with 99 specific recommendations. Each is categorized as category IA, category IB, category IC, category II, or unresolved issue (**Table 1**). The recommendations most relevant to the practice of interventional radiology are given as follows, with supporting information and references. Note that the organization and numbering used here differ from those used in the CDC guideline.

GENERAL RECOMMENDATIONS

General recommendations are provided in **Table 2** (29–40).

A meta-analysis of 14 randomized, controlled trials evaluating the effects of prophylactic doses of heparin or heparin bonding on thrombus formation and infection associated with CVCs and pulmonary artery catheters found that heparin administration reduces thrombus formation and may reduce catheter-related infections in patients with these catheters (40). Heparin significantly decreases CVC-related thrombosis, decreases bacterial colonization of the catheter, and may decrease catheter-related bacteremia. To decrease the risk of major vessel thrombosis, unfractionated heparin must be administered in doses of at least 3 U/mL total parenteral nutrition, or 5,000 U every 6 hours or every 12 hours, and low molecular weight heparin must be administered in doses of at least 2,500 U subcutaneously daily. Lower doses may not be effective (40).

Catheter and Site Selection

Recommendations for catheter and site selection are provided in **Table 3** (11,41–67).

The site at which a catheter is placed influences the subsequent risk for catheter-related infection and phlebitis. The influence of site on the risk for catheter infections is related in part to the risk for thrombophlebitis and in part on the density of local skin flora.

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