Guidelines for the Prevention of Intravascular Catheter–Related Infections

Naomi P. O'Grady,[1] Mary Alexander,[2] E. Patchen Dellinger,[5] Julie L. Gerberding,[6] Stephen O. Heard,[3] Dennis G. Maki,[8] Henry Masur,[1] Rita D. McCormick,[9] Leonard A. Mermel,[10] Michele L. Pearson,[7] Issam I. Raad,[11] Adrienne Randolph,[4] and Robert A. Weinstein[12]

[1]National Institutes of Health, Bethesda, Maryland; [2]Infusion Nurses Society, Cambridge, and [3]University of Massachusetts Medical School, Worcester, and [4]The Children's Hospital, Boston, Massachusetts; [5]University of Washington, Seattle; [6]Office of the Director, Centers for Disease Control and Prevention (CDC), and [7]Division of Healthcare Quality Promotion, National Center for Infectious Diseases, CDC, Atlanta, Georgia; University of Wisconsin [8]Medical School and [9]Hospital and Clinics, Madison; [10]Rhode Island Hospital and Brown University School of Medicine, Providence, Rhode Island; [11]MD Anderson Cancer Center, Houston, Texas; and [12]Cook County Hospital and Rush Medical College, Chicago, Illinois

These guidelines have been developed for practitioners who insert catheters and for persons responsible for surveillance and control of infections in hospital, outpatient, and home health-care settings. This report 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 (SCCM), in collaboration with the Infectious Disease Society of America (IDSA), Society for Healthcare Epidemiology of America (SHEA), Surgical Infection Society (SIS), American College of Chest Physicians (ACCP), American Thoracic Society (ATS), American Society of Critical Care Anesthesiologists (ASCCA), Association for Professionals in Infection Control and Epidemiology (APIC), Infusion Nurses Society (INS), Oncology Nursing Society (ONS), Society of Cardiovascular and Interventional Radiology (SCVIR), American Academy of Pediatrics (AAP), and the Healthcare Infection Control Practices Advisory Committee (HICPAC) of the Centers for Disease Control and Prevention (CDC) and is intended to replace the Guideline for Prevention of Intravascular Device–Related Infections published in 1996. These guidelines are intended to provide evidence-based recommendations for preventing catheter-related infections. Major areas of emphasis include 1) educating and training health-care providers who insert and maintain catheters; 2) using maximal sterile barrier precautions during central venous catheter insertion; 3) using a 2% chlorhexidine preparation for skin antisepsis; 4) avoiding routine replacement of central venous catheters as a strategy to prevent infection; and 5) using antiseptic/antibiotic impregnated short-term central venous catheters if the rate of infection is high despite adherence to other strategies (i.e., education and training, maximal sterile barrier precautions, and 2% chlorhexidine for skin antisepsis). These guidelines also identify performance indicators that can be used locally by health-care institutions or organizations to monitor their success in implementing these evidence-based recommendations.

INTRODUCTION

This report provides health-care practitioners with background information and specific recommendations to reduce the incidence of intravascular catheter-related bloodstream infections (CRBSI). These guidelines replace the *Guideline for Prevention of Intravascular Device–Related Infections*, which was published in 1996 [1].

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INTRAVASCULAR CATHETER–RELATED INFECTIONS IN ADULT AND PEDIATRIC PATIENTS: AN OVERVIEW

Background

Intravascular catheters are indispensable in modern-day medical practice, particularly in intensive care units (ICUs). Although such catheters provide necessary vascular access, their use puts patients at risk for local and systemic infectious complications, including local site infection, CRBSI, septic thrombophlebitis, endocarditis, and other metastatic infections (e.g., lung abscess, brain abscess, osteomyelitis, and endophthalmitis).

Health-care institutions purchase millions of intravascular catheters each year. The incidence of CRBSI varies considerably by type of catheter, frequency of catheter manipulation, and patient-related factors (e.g., underlying disease and acuity of illness). Peripheral venous catheters are the devices most frequently used for vascular access. Although the incidence of local or bloodstream infections (BSIs) associated with peripheral venous catheters is usually low, serious infectious complications produce considerable annual morbidity because of the frequency with which such catheters are used. However, the majority of serious catheter-related infections are associated with central venous catheters (CVCs), especially those that are placed in patients in ICUs. In the ICU setting, the incidence of infection is often higher than in the less acute in-patient or ambulatory setting. In the ICU, central venous access might be needed for extended periods of time; patients can be colonized with hospital-acquired organisms; and the catheter can be manipulated multiple times per day for the administration of fluids, drugs, and blood products. Moreover, some catheters can be inserted in urgent situations, during which optimal attention to aseptic technique might not be feasible. Certain catheters (e.g., pulmonary artery catheters and peripheral arterial catheters) can be accessed multiple times per day for hemodynamic measurements or to obtain samples for laboratory analysis, augmenting the potential for contamination and subsequent clinical infection.

The magnitude of the potential for CVCs to cause morbidity and mortality resulting from infectious complications has been estimated in several studies [2]. In the United States, 15 million CVC days (i.e., the total number of days of exposure to CVCs by all patients in the selected population during the selected time period) occur in ICUs each year [2]. If the average rate of CVC-associated BSIs is 5.3 per 1,000 catheter days in the ICU [3], approximately 80,000 CVC-associated BSIs occur in ICUs each year in the United States. The attributable mortality for these BSIs has ranged from no increase in mortality in studies that controlled for severity of illness [4–6], to 35% increase in mortality in prospective studies that did not use this control [7, 8]. Thus, the attributable mortality remains unclear. The attributable cost per infection is an estimated $34,508–$56,000 [5, 9], and the annual cost of caring for patients with CVC-associated BSIs ranges from $296 million to $2.3 billion [10].

A total of 250,000 cases of CVC-associated BSIs have been estimated to occur annually if entire hospitals are assessed rather than ICUs exclusively [11]. In this case, attributable mortality is an estimated 12%–25% for each infection, and the marginal cost to the health-care system is $25,000 per episode [11].

Therefore, by several analyses, the cost of CVC-associated BSI is substantial, both in terms of morbidity and in terms of financial resources expended. To improve patient outcome and reduce health-care costs, strategies should be implemented to reduce the incidence of these infections. This effort should be multidisciplinary, involving health-care professionals who insert and maintain intravascular catheters, health-care managers who allocate resources, and patients who are capable of assisting in the care of their catheters. Although several individual strategies have been studied and shown to be effective in reducing CRBSI, studies using multiple strategies have not been conducted. Thus, it is not known whether implementing multiple strategies will have an additive effect in reducing CRBSI, but it is logical to use multiple strategies concomitantly.

Terminology and Estimates of Risk

The terminology used to identify different types of catheters is confusing, because many clinicians and researchers use different

aspects of the catheter for informal reference. A catheter can be designated by the type of vessel it occupies (e.g., peripheral venous, central venous, or arterial); its intended life span (e.g., temporary or short-term versus permanent or long-term); its site of insertion (e.g., subclavian, femoral, internal jugular, peripheral, and peripherally inserted central catheter [PICC]); its pathway from skin to vessel (e.g., tunneled versus nontunneled); its physical length (e.g., long versus short); or some special characteristic of the catheter (e.g., presence or absence of a cuff, impregnation with heparin, antibiotics or antiseptics, and the number of lumens). To accurately define a specific type of catheter, all of these aspects should be described (table 1).

The rate of all catheter-related infections (including local infections and systemic infections) is difficult to determine. Although CRBSI is an ideal parameter because it represents the most serious form of catheter-related infection, the rate of such infection depends on how CRBSI is defined.

Health-care professionals should recognize the difference between surveillance definitions and clinical definitions. The surveillance definitions for catheter-associated BSI includes all BSIs that occur in patients with CVCs, when other sites of infection have been excluded (Appendix A). That is, the surveillance definition overestimates the true incidence of CRBSI because not all BSIs originate from a catheter. Some bacteremias are secondary BSIs from undocumented sources (e.g., postoperative surgical sites, intra-abdominal infections, and hospital-associated pneumonia or urinary tract infections). Thus, surveillance definitions are really definitions for catheter-associated BSIs. A more rigorous definition might include only those BSIs for which other sources were excluded by careful examination of the patient record, and where a culture of the catheter tip demonstrated substantial colonies of an organism identical to those found in the bloodstream. Such a clinical definition would focus on catheter-related BSIs. Therefore, to accurately compare a health-care facility's infection rate to published data, comparable definitions also should be used.

CDC and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) recommend that the rate of catheter-associated BSIs be expressed as the number of catheter associated BSIs per 1,000 CVC days [12, 13]. This parameter is more useful than the rate expressed as the number of catheter-associated infections per 100 catheters (or percentage of catheters studied), because it accounts for BSIs

Table 1. Catheters used for venous and arterial access.

Catheter type	Entry Site	Length	Comments
Peripheral venous catheters (short)	Usually inserted in veins of forearm or hand	<3 inches	Phlebitis with prolonged use; rarely associated with bloodstream infection
Peripheral arterial catheters	Usually inserted in radial artery; can be placed in femoral, axillary, brachial, posterior tibial arteries	<3 inches	Low infection risk; rarely associated with bloodstream infection
Midline catheters	Inserted via the antecubital fossa into the proximal basilic or cephalic veins; does not enter central veins, peripheral catheters	3 to 8 inches	Anaphylactoid reactions have been reported with catheters made of elastomeric hydrogel; lower rates of phlebitis than short peripheral catheters
Nontunneled central venous catheters	Percutaneously inserted into central veins (subclavian, internal jugular, or femoral)	⩾8 cm depending on patient size	Account for majority of CRBSI
Pulmonary artery catheters	Inserted through a Teflon introducer in a central vein (subclavian, internal jugular, or femoral)	⩾30 cm depending on patient size	Usually heparin bonded; similar rates of bloodstream infection as CVCs; subclavian site preferred to reduce infection risk
Peripherally inserted central venous catheters (PICC)	Inserted into basilic, cephalic, or brachial veins and enter the superior vena cava	⩾20 cm depending on patient size	Lower rate of infection nontunneled CVCs
Tunneled central venous catheters	Implanted into subclavian, internal jugular, or femoral veins	⩾8 cm depending on patient size	Cuff inhibits migration of organisms into catheter tract; lower rate of infection than nontunnelled CVC
Totally implantable	Tunneled beneath skin and have subcutaneous port accessed with a needle; implanted in subclavian or internal jugular vein	⩾8 cm depending on patient size	Lowest risk for CRBSI; improved patient self-image; no need for local catheter-site care; surgery required for catheter removal
Umbilical catheters	Inserted into either umbilical vein or umbilical artery	⩽6 cm depending on patient size	Risk for CRBSI similar catheters placed in umbilical vein vs. artery

Table 2. Pooled means of the distribution of central venous catheter-associated bloodstream infection rates in hospitals reporting to the National Nosocomial Infection Surveillance System, January 1992–June 2001 (issued August 2001).

Type of ICU	No. of ICUs	Catheter days	Pooled mean/ 1000 catheter days
Coronary	102	252,325	4.5
Cardiothoracic	64	419,674	2.9
Medical	135	671,632	5.9
Medical/surgical			
Major teaching	123	579,704	5.3
All others	180	863,757	3.8
Neurosurgical	47	123,780	4.7
Nursery, high risk (HRN)			
⩽1000 g	138	438,261	11.3
1001–1500 g	136	213,351	6.9
1501–2500 g	132	163,697	4.0
>2500 g	133	231,573	3.8
Pediatric	74	291,831	7.6
Surgical	153	900,948	5.3
Trauma	25	116,709	7.9
Respiratory	7	21,265	3.4

NOTE. From [290, 291].

over time and therefore adjusts risk for the number of days the catheter is in use.

Epidemiology and Microbiology

Since 1970, CDC's National Nosocomial Infection Surveillance System (NNIS) has been collecting data on the incidence and etiologies of hospital-acquired infections, including CVC-associated BSIs in a group of nearly 300 U.S. hospitals. The majority of hospital-acquired BSIs are associated with the use of a CVC, with BSI rates being substantially higher among patients with CVCs than among those without CVCs. Rates of CVC-associated BSI vary considerably by hospital size, hospital service/unit, and type of CVC. During 1992–2001, NNIS hospitals reported ICU rates of CVC-associated BSI ranging from 2.9 (in a cardiothoracic ICU) to 11.3 (in a neonatal nursery for infants weighing <1,000 g) BSIs per 1,000 CVC days (table 2) [14].

The relative risk of catheter-associated BSI also has been assessed in a meta-analysis of 223 prospective studies of adult patients [11]. Relative risk of infection was best determined by analyzing rates of infection both by BSIs per 100 catheters and BSIs per 1,000 catheter days. These rates, and the NNIS-derived data, can be used as benchmarks by individual hospitals to estimate how their rates compare with other institutions. Rates are influenced by patient-related parameters, such as severity of illness and type of illness (e.g., third-degree burns versus postcardiac surgery), and by catheter-related parameters, such as the condition under which the catheter was placed (e.g., elective versus urgent) and catheter type (e.g., tunneled versus nontunneled or subclavian versus jugular).

Types of organisms that most commonly cause hospital-acquired BSIs change over time. During 1986–1989, coagulase-negative staphylococci, followed by *Staphylococcus aureus*, were the most frequently reported causes of BSIs, accounting for 27% and 16% of BSIs, respectively (table 3) [15]. Pooled data from 1992 through 1999 indicate that coagulase-negative staphylococci, followed by enterococci, are now the most frequently isolated causes of hospital-acquired BSIs [12]. Coagulase-negative staphylococci account for 37% [12] and *S. aureus* account for 12.6% of reported hospital-acquired BSIs [12]. Also notable was the susceptibility pattern of *S. aureus* isolates. In 1999, for the first time since NNIS has been reporting susceptibilities, >50% of all *S. aureus* isolates from ICUs were resistant to oxacillin [12].

In 1999, enterococci accounted for 13.5% of BSIs, an increase from 8% reported to NNIS during 1986–1989. The percentage of enterococcal ICU isolates resistant to vancomycin also is increasing, escalating from 0.5% in 1989 to 25.9% in 1999 [12].

Candida spp. caused 8% of hospital-acquired BSIs reported to NNIS during 1986–1989 [15, 16], and during 1992–1999 [12, 17, 18]. Resistance of *Candida* spp. to commonly used antifungal agents is increasing. Although NNIS has not reported the percentage of BSIs caused by nonalbicans species or fluconazole susceptibility data, other epidemiologic and clinical data document that fluconazole resistance is an increasingly relevant consideration when designing empiric therapeutic regimens for CRBSIs caused by yeast. Data from the Surveillance and Control of Pathogens of Epidemiologic Importance (SCOPE) Program documented that 10% of *C. albicans* bloodstream isolates from hospitalized patients were resistant to fluconazole [17]. Additionally, 48% of *Candida* BSIs were caused by nonalbicans species, including *C. glabrata* and *C. krusei,*

Table 3. Most common pathogens isolated from bloodstream infections.

Pathogen	1986–1989, %	1992–1999, %
Coagulase-negative staphylococci	27	37
Staphylococcus aureus	16	13
Enterococcus	8	13
Gram-negative rods	19	14
E. coli	6	2
Enterobacter	5	5
P. aeruginosa	4	4
K. pneumoniae	4	3
Candida spp.	8	8

NOTE. From [12, 15].

which are more likely than *C. albicans* to demonstrate resistance to fluconazole and itraconazole [18, 19].

Gram-negative bacilli accounted for 19% of catheter-associated BSIs during 1986–1989 [15] compared with 14% of catheter-associated BSIs during 1992–1999 [12]. An increasing percentage of ICU-related isolates are caused by *Enterobacteriaceae* that produce extended-spectrum β-lactamases (ESBLs), particularly *Klebsiella pneumoniae* [20]. Such organisms not only are resistant to extended-spectrum cephalosporins, but also to frequently used, broad-spectrum antimicrobial agents.

Pathogenesis

Migration of skin organisms at the insertion site into the cutaneous catheter tract with colonization of the catheter tip is the most common route of infection for peripherally inserted, short-term catheters [21, 22]. Contamination of the catheter hub contributes substantially to intraluminal colonization of long-term catheters [23–25]. Occasionally, catheters might become hematogenously seeded from another focus of infection. Rarely, infusate contamination leads to CRBSI [26].

Important pathogenic determinants of catheter-related infection are (1) the material of which the device is made and (2) the intrinsic virulence factors of the infecting organism. In vitro studies demonstrate that catheters made of polyvinyl chloride or polyethylene are likely less resistant to the adherence of microorganisms than are catheters made of Teflon, silicone elastomer, or polyurethane [27, 28]. Therefore, the majority of catheters sold in the United States are no longer made of polyvinyl chloride or polyethylene. Some catheter materials also have surface irregularities that enhance the microbial adherence of certain species (e.g., coagulase-negative staphylococci, *Acinetobacter calcoaceticus*, and *Pseudomonas aeruginosa*) [29–31]; catheters made of these materials are especially vulnerable to microbial colonization and subsequent infection. Additionally, certain catheter materials are more thrombogenic than others, a characteristic that also might predispose to catheter colonization and catheter-related infection [31, 32]. This association has led to emphasis on preventing catheter-related thrombus as an additional mechanism for reducing CRBSI.

The adherence properties of a given microorganism also are important in the pathogenesis of catheter-related infection. For example, *S. aureus* can adhere to host proteins (e.g., fibronectin) commonly present on catheters [33, 34]. Also, coagulase-negative staphylococci adhere to polymer surfaces more readily than do other pathogens (e.g., *Escherichia coli* or *S. aureus*). Additionally, certain strains of coagulase-negative staphylococci produce an extracellular polysaccharide often referred to as "slime" [35, 36]. In the presence of catheters, this slime potentiates the pathogenicity of coagulase-negative staphylococci by allowing them to withstand host defense mechanisms (e.g., acting as a barrier to engulfment and killing by polymorphonuclear leukocytes) or by making them less susceptible to antimicrobial agents (e.g., forming a matrix that binds antimicrobials before their contact with the organism cell wall) [37]. Certain *Candida* spp., in the presence of glucose-containing fluids, might 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 [38].

STRATEGIES FOR PREVENTION OF CATHETER-RELATED INFECTIONS IN ADULT AND PEDIATRIC PATIENTS

Quality Assurance and Continuing Education

Measures to minimize the risk for infection associated with intravascular therapy should strike a balance between patient safety and cost effectiveness. As knowledge, technology, and health-care settings change, infection control and prevention measures also should change. Well-organized programs that enable health-care providers to provide, monitor, and evaluate care and to become educated are critical to the success of this effort. Reports spanning the past two decades have consistently demonstrated that risk for infection declines following standardization of aseptic care [39–43], and that insertion and maintenance of intravascular catheters by inexperienced staff might increase the risk for catheter colonization and CRBSI [43, 44]. Specialized "IV teams" have shown unequivocal effectiveness in reducing the incidence of catheter-related infections and associated complications and costs [45–47]. Additionally, infection risk increases with nursing staff reductions below a critical level [48].

Site of Catheter Insertion

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 density of local skin flora.

Phlebitis has long been recognized as a risk for infection. For adults, lower extremity insertion sites are associated with a higher risk for infection than are upper extremity sites [49–51]. In addition, hand veins have a lower risk for phlebitis than do veins on the wrist or upper arm [52].

The density of skin flora at the catheter insertion site is a major risk factor for CRBSI. Authorities recommend that CVCs be placed in a subclavian site instead of a jugular or femoral site to reduce the risk for infection. No randomized trial satisfactorily has compared infection rates for catheters placed in jugular, subclavian, and femoral sites. Catheters inserted into an internal jugular vein have been associated with higher risk for infection than those inserted into a subclavian or femoral vein [22, 53, 54].

Femoral catheters have been demonstrated to have relatively high colonization rates when used in adults [55]. Femoral catheters should be avoided, when possible, because they are associated with a higher risk for deep venous thrombosis than are internal jugular or subclavian catheters [56–60] and because of a presumption that such catheters are more likely to become infected. However, studies in pediatric patients have demonstrated that femoral catheters have a low incidence of mechanical complications and might have an equivalent infection rate to that of nonfemoral catheters [61–63]. Thus, in adult patients, a subclavian site is preferred for infection control purposes, although other factors (e.g., the potential for mechanical complications, risk for subclavian vein stenosis, and catheter-operator skill) should be considered when deciding where to place the catheter. In a meta-analysis of eight studies, the use of bedside ultrasound for the placement of CVCs substantially reduced mechanical complications compared with the standard landmark placement technique (relative risk [RR], 0.22; 95% confidence interval [CI], 0.10–0.45) [64]. Consideration of comfort, security, and maintenance of asepsis as well as patient-specific factors (e.g., preexisting catheters, anatomic deformity, and bleeding diathesis), relative risk of mechanical complications (e.g., bleeding and pneumothorax), the availability of bedside ultrasound, and the risk for infection should guide site selection.

Type of Catheter Material

Teflon or polyurethane catheters have been associated with fewer infectious complications than catheters made of polyvinyl chloride or polyethylene [27, 65, 66]. Steel needles used as an alternative to catheters for peripheral venous access have the same rate of infectious complications as do Teflon catheters [67, 68]. However, the use of steel needles frequently is complicated by infiltration of intravenous (IV) fluids into the subcutaneous tissues, a potentially serious complication if the infused fluid is a vesicant [68].

Hand Hygiene and Aseptic Technique

For short peripheral catheters, good hand hygiene before catheter insertion or maintenance, combined with proper aseptic technique during catheter manipulation, provides protection against infection. Good hand hygiene can be achieved through the use of either a waterless, alcohol-based product [69] or an antibacterial soap and water with adequate rinsing [70]. Appropriate aseptic technique does not necessarily require sterile gloves; a new pair of disposable nonsterile gloves can be used in conjunction with a "no-touch" technique for the insertion of peripheral venous catheters. However, gloves are required by the Occupational Safety and Health Administration as standard precautions for the prevention of bloodborne pathogen exposure.

Compared with peripheral venous catheters, CVCs carry a substantially greater risk for infection; therefore, the level of barrier precautions needed to prevent infection during insertion of CVCs should be more stringent. Maximal sterile barrier precautions (e.g., cap, mask, sterile gown, sterile gloves, and large sterile drape) during the insertion of CVCs substantially reduces the incidence of CRBSI compared with standard precautions (e.g., sterile gloves and small drapes) [22, 71]. Although the efficacy of such precautions for insertion of PICCs and midline catheters has not been studied, the use of maximal barrier precautions also is probably applicable to PICCs.

Skin Antisepsis

In the United States, povidone iodine has been the most widely used antiseptic for cleansing arterial catheter and CVC insertion sites [72]. However, in one study, preparation of central venous and arterial sites with a 2% aqueous chlorhexidine gluconate lowered BSI rates compared with site preparation with 10% povidone-iodine or 70% alcohol [73]. Commercially available products containing chlorhexidine have not been available until recently; in July 2000, the US Food and Drug Administration (FDA) approved a 2% tincture of chlorhexidine preparation for skin antisepsis. Other preparations of chlorhexidine might not be as effective. Tincture of chlorhexidine gluconate 0.5% is no more effective in preventing CRBSI or CVC colonization than 10% povidone iodine, as demonstrated by a prospective, randomized study of adults [74]. However, in a study involving neonates, 0.5% chlorhexidine reduced peripheral IV colonization compared with povidone iodine (20/418 versus 38/408 catheters; $P = .01$) [75]. This study, which did not include CVCs, had an insufficient number of participants to assess differences in BSI rates. A 1% tincture of chlorhexidine preparation is available in Canada and Australia, but not yet in the United States. No published trials have compared a 1% chlorhexidine preparation to povidone-iodine.

Catheter Site Dressing Regimens

Transparent, semipermeable polyurethane dressings have become a popular means of dressing catheter insertion sites. Transparent dressings reliably secure the device, permit continuous visual inspection of the catheter site, permit patients to bathe and shower without saturating the dressing, and require less frequent changes than do standard gauze and tape dressings; the use of these dressings saves personnel time.

In the largest controlled trial of dressing regimens on peripheral catheters, the infectious morbidity associated with the use of transparent dressings on approximately 2000 peripheral catheters was examined [65]. Data from this study suggest that the rate of colonization among catheters dressed with transparent dressings (5.7%) is comparable to that of those dressed with gauze (4.6%) and that no clinically substantial differences

exist in either the incidences of catheter-site colonization or phlebitis. Furthermore, these data suggest that transparent dressings can be safely left on peripheral venous catheters for the duration of catheter insertion without increasing the risk for thrombophlebitis [65].

A meta-analysis has assessed studies that compared the risk for catheter-related BSIs for groups using transparent dressings versus groups using gauze dressing [76]. The risk for CRBSIs did not differ between the groups. The choice of dressing can be a matter of preference. If blood is oozing from the catheter insertion site, gauze dressing might be preferred.

In a multi-center study, a chlorhexidine-impregnated sponge (Biopatch) placed over the site of short-term arterial and CVCs reduced the risk for catheter colonization and CRBSI [77]. No adverse systemic effects resulted from use of this device.

Catheter Securement Devices

Sutureless securement devices can be advantageous over suture in preventing catheter-related BSIs. One study, which involved only a limited number of patients and was underpowered, compared a sutureless device with suture for the securement of PICCS; in this study, CRBSI was reduced in the group of patients that received the sutureless device [78].

In-Line Filters

In-line filters reduce the incidence of infusion-related phlebitis [79, 80]. No data support their efficacy in preventing infections associated with intravascular catheters and infusion systems. Proponents of filters cite several potential benefits to using these filters, including (1) reducing the risk for infection from contaminated infusate or proximal contamination (i.e., introduced proximal to the filter); (2) reducing the risk for phlebitis in patients who require high doses of medication or in those in whom infusion-related phlebitis already has occurred; (3) removing particulate matter that might contaminate IV fluids [81]; and (4) filtering endotoxin produced by gram-negative organisms in contaminated infusate [82]. These theoretical advantages should be tempered by the knowledge that infusate-related BSI is rare and that filtration of medications or infusates in the pharmacy is a more practical and less costly way to remove the majority of particulates. Furthermore, in-line filters might become blocked, especially with certain solutions (e.g., dextran, lipids, and mannitol), thereby increasing the number of line manipulations and decreasing the availability of administered drugs [83]. Thus, for reducing the risk for CRBSI, no strong recommendation can be made in favor of using in-line filters.

Antimicrobial/Antiseptic Impregnated Catheters and Cuffs

Certain catheters and cuffs that are coated or impregnated with antimicrobial or antiseptic agents can decrease the risk for CRBSI and potentially decrease hospital costs associated with treating CRBSIs, despite the additional acquisition cost of an antimicrobial/antiseptic impregnated catheter [84]. All of the studies involving antimicrobial/antiseptic impregnated catheters have been conducted using triple-lumen, noncuffed catheters in adult patients whose catheters remained in place <30 days. Although all of the studies have been conducted in adults, these catheters have been approved by FDA for use in patients weighing >3 kg. No antiseptic or antimicrobial impregnated catheters currently are available for use in weighing <3 kg.

Chlorhexidine/silver sulfadiazine. Catheters coated with chlorhexidine/silver sulfadiazine only on the external luminal surface have been studied as a means to reduce CRBSI. Two meta-analyses [2, 85] demonstrated that such catheters reduced the risk for CRBSI compared with standard noncoated catheters. The mean duration of catheter placement in one meta-analysis ranged from 5.1 to 11.2 days [86]. The half-life of antimicrobial activity against *S. epidermidis* is 3 days in vitro for catheters coated with chlorhexidine/silver sulfadiazine; this antimicrobial activity decreases over time [87]. The benefit for the patients who receive these catheters will be realized within the first 14 days [86]. A second-generation catheter is now available with chlorhexidine coating both the internal and external luminal surfaces. The external surface has three times the amount of chlorhexidine and extended release of the surface bound antiseptics than that in the first generation catheters. The external surface coating of chlorhexidine is combined with silver-sulfadiazine, and the internal surface is coated with chlorhexidine alone. Preliminary studies indicate that prolonged anti-infective activity provides improved efficacy in preventing infections [88]. Although rare, anaphylaxis has been reported with the use of these chlorhexidine/silver sulfadiazine catheters in Japan [89]. Whether patients will become colonized or infected with organisms resistant to chlorhexidine/silver sulfadiazine has not been determined [86].

Chlorhexidine/silver sulfadiazine catheters are more expensive than standard catheters. However, one analysis has suggested that the use of chlorhexidine/silver sulfadiazine catheters should lead to a cost savings of $68 to $391 per catheter [90] in settings in which the risk for CRBSI is high despite adherence to other preventive strategies (e.g., maximal barrier precautions and aseptic techniques). Use of these catheters might be cost effective in ICU patients, burn patients, neutropenic patients, and other patient populations in which the rate of infection exceeds 3.3 per 1000 catheter days [86].

Minocycline/rifampin. In a multicenter randomized trial, CVCs impregnated on both the external and internal surfaces with minocycline/rifampin were associated with lower rates of CRBSI when compared with the first-generation chlorhexidine–silver sulfadiazine impregnated catheters [91]. The beneficial effect began after day 6 of catheterization. None of the

catheters were evaluated beyond 30 days. No minocycline/rifampin–resistant organisms were reported. However, in vitro data indicate that these impregnated catheters could increase the incidence of minocycline and rifampin resistance among pathogens, especially staphylococci. The half-life of antimicrobial activity against *S. epidermidis* is 25 days with catheters coated with minocycline/rifampin, compared with 3 days for the first-generation catheters coated with chlorhexidine/silver sulfadiazine in vitro [87]. In vivo, the duration of antimicrobial activity of the minocycline/rifampin catheter is longer than that of the first-generation chlorhexidine/silver sulfadiazine catheter [91]. No comparative studies have been published using the second-generation chlorhexidine/ silver sulfadiazine catheter. Studies are needed to evaluated whether the improved performance of the minocyline/rifampin catheters results from the antimicrobial agents used or from the coating of both the internal and external surfaces. As with chlorhexidine/silver sulfadiazine catheters, some clinicians have recommended that the minocycline/rifampin catheters be considered in patient populations when the rate of CRBSI exceeds 3.3 per 1000 catheter days [86]. Others suggest that reducing all rates of CRBSI should be the goal [92]. The decision to use chlorhexidine/ silver sulfadiazine or minocycline/rifampin impregnated catheters should be based on the need to enhance prevention of CRBSI after standard procedures have been implemented (e.g., educating personnel, using maximal sterile barrier precautions, and using 2% chlorhexidine skin antisepsis) and then balanced against the concern for emergence of resistant pathogens and the cost of implementing this strategy.

Platinum/silver. Ionic metals have broad antimicrobial activity and are being used in catheters and cuffs to prevent CRBSI. A combination platinum/silver impregnated catheter is available in Europe and has recently been approved by FDA for use in the United States. Although these catheters are being marketed for their antimicrobial properties, no published studies have been presented to support an antimicrobial effect.

Silver cuffs. Ionic silver has been used in subcutaneous collagen cuffs attached to CVCs [93]. The ionic silver provides antimicrobial activity and the cuff provides a mechanical barrier to the migration of microorganisms along the external surface of the catheter. In studies of catheters left in place >20 days, the cuff failed to reduce the incidence of CRBSI [94, 95]. Two other studies of short-term catheters could not demonstrate efficacy because of the minimal number of CRBSIs observed [93, 96].

Systemic Antibiotic Prophylaxis

No studies have demonstrated that oral or parenteral antibacterial or antifungal drugs might reduce the incidence of CRBSI among adults [97–99]. However, among low birth weight infants, two studies have assessed vancomycin prophylaxis; both demonstrated a reduction in CRBSI but no reduction in mortality [100, 101]. Because the prophylactic use of vancomycin is an independent risk factor for the acquisition of vancomycin-resistant enterococcus (VRE) [102], the risk for acquiring VRE likely outweighs the benefit of using prophylactic vancomycin.

Antibiotic/Antiseptic Ointments

Povidone-iodine ointment applied at the insertion site of hemodialysis catheters has been studied as a prophylactic intervention to reduce the incidence of catheter-related infections. One randomized study of 129 hemodialysis catheters demonstrated a reduction in the incidence of exit-site infections, catheter-tip colonization, and BSIs with the routine use of povidone-iodine ointment at the catheter insertion site compared with no ointment at the insertion site [103].

Several studies have evaluated the effectiveness of mupirocin ointment applied at the insertion sites of CVCs as a means to prevent CRBSI [104–106]. Although mupirocin reduced the risk for CRBSI [106], mupirocin ointment also has been associated with mupirocin resistance [107, 108], and might adversely affect the integrity of polyurethane catheters [109, 110].

Nasal carriers of *S. aureus* have a higher risk for acquiring CRBSI than do noncarriers [103, 111]. Mupirocin ointment has been used intranasally to decrease nasal carriage of *S. aureus* and lessen the risk for CRBSI. However, resistance to mupirocin develops in both *S. aureus* and coagulase-negative staphylococci soon after routine use of mupirocin is instituted [107, 108].

Other antibiotic ointments applied to the catheter insertion site also have been studied and have yielded conflicting results [112–114]. In addition, rates of catheter colonization with *Candida* spp. might be increased with the use of antibiotic ointments that have no fungicidal activity [112, 114]. To avoid compromising the integrity of the catheter, any ointment that is applied to the catheter insertion site should be checked against the catheter and ointment manufacturers' recommendations regarding compatibility.

Antibiotic Lock Prophylaxis

To prevent CRBSI, antibiotic lock prophylaxis has been attempted by flushing and filling the lumen of the catheter with an antibiotic solution and leaving the solution to dwell in the lumen of the catheter. Three studies have demonstrated the usefulness of such prophylaxis in neutropenic patients with long-term catheters [115–117]. In two of the studies, patients received either heparin alone (10 U/mL) or heparin plus 25 micrograms/mL of vancomycin. The third study compared vancomycin/ciprofloxacin/heparin (VCH) to vancomycin/heparin (VH) and then to heparin alone. The rate of CRBSI with vancomycin-susceptible organisms was significantly lower (VCH, $P = .022$; VH, $P = .028$) and the time to the first episode of bacteremia with vancomycin-susceptible organisms was sub-

stantially longer (VCH, $P = .036$; VH, $P = .011$) in patients receiving either vancomycin/ciprofloxacin/heparin or vancomycin/heparin compared with heparin alone [115–117]. One study involving a limited number of children revealed no difference in rates of CRBSI between children receiving a heparin flush compared with those receiving heparin and vancomycin [118]. However, because the use of vancomycin is an independent risk factor for the acquisition of VRE [102], this practice is not recommended routinely.

An anticoagulant/antimicrobial combination comprising minocycline and ethylenediaminetetraraacetic acid (EDTA) has been proposed as a lock solution because it has antibiofilm and antimicrobial activity against gram-positive, gram-negative, and *Candida* organisms [119], as well as anticoagulant properties. However, no controlled or randomized trials have demonstrated its efficacy.

Anticoagulants

Anticoagulant flush solutions are used widely to prevent catheter thrombosis. Because thrombi and fibrin deposits on catheters might serve as a nidus for microbial colonization of intravascular catheters [120, 121], the use of anticoagulants might have a role in the prevention of CRBSI.

In a meta-analysis evaluating the benefit of heparin prophylaxis (3 U/mL in TPN, 5000 U every 6 or 12 hours flush, or 2500 U low molecular weight heparin subcutaneously) in patients with short-term CVCs, the risk for catheter-related central venous thrombosis was reduced with the use of prophylactic heparin [122]. However, no substantial difference in the rate for CRBSI was observed. Because the majority of heparin solutions contain preservatives with antimicrobial activity, whether any decrease in the rate of CRBSI is a result of the reduced thrombus formation, the preservative, or both is unclear.

The majority of pulmonary artery, umbilical, and central venous catheters are available with a heparin-bonded coating. The majority are heparin-bonded with benzalkonium chloride, which provides the catheters with antimicrobial activity [123] and provides an anti-thrombotic effect [124].

Warfarin also has been evaluated as a means for reducing CRBSI by reducing thrombus formation on catheters [125, 126]. In patients with long-term CVCs, low-dose warfarin (i.e., 1 mg/day) reduced the incidence of catheter thrombus. No data demonstrate that warfarin reduces the incidence of CRBSI.

REPLACEMENT OF CATHETERS

Peripheral Venous Catheters

Scheduled replacement of intravascular catheters has been proposed as a method to prevent phlebitis and catheter-related infections. Studies of short peripheral venous catheters indicate that the incidence of thrombophlebitis and bacterial colonization of catheters increases when catheters are left in place >72 hours [66, 67, 127]. However, rates of phlebitis are not substantially different in peripheral catheters left in place 72 hours compared with 96 hours [128]. Because phlebitis and catheter colonization have been associated with an increased risk for catheter-related infection, short peripheral catheter sites commonly are rotated at 72–96-hour intervals to reduce both the risk for infection and patient discomfort associated with phlebitis.

Midline Catheters

Midline catheters have been associated with lower rates of phlebitis than short peripheral catheters and with lower rates of infection than CVCs [129–131]. In one prospective study of 140 midline catheters, their use was associated with a BSI rate of 0.8 per 1000 catheter days [131]. No specific risk factors, including duration of catheterization, were associated with infection. Midline catheters were in place a median of 7 days, but for as long as 49 days. Although the findings of this study suggested that midline catheters can be changed only when there is a specific indication, no prospective, randomized studies have assessed the benefit of routine replacement as a strategy to prevent CRBSI associated with midline catheters.

CVCs, Including PICCs and Hemodialysis Catheters

Catheter replacement at scheduled time intervals as a method to reduce CRBSI has not lowered rates. Two trials have assessed a strategy of changing the catheter every 7 days compared with a strategy of changing catheters as needed [132, 133]. One of these studies involved 112 surgical ICU patients needing CVCs, pulmonary artery catheters, or peripheral arterial catheters [132], whereas the other study involved only subclavian hemodialysis catheters [133]. In both studies, no difference in CRBSI was observed in patients undergoing scheduled catheter replacement every 7 days compared with patients whose catheters were replaced as needed.

Scheduled guidewire exchanges of CVCs is another proposed strategy for preventing CRBSI. The results of a meta-analysis of 12 randomized controlled trials assessing CVC management failed to prove any reduction of CRBSI rates through routine replacement of CVCs by guidewire exchange compared with catheter replacement on an as-needed basis [134]. Thus, routine replacement of CVCs is not necessary for catheters that are functioning and have no evidence of causing local or systemic complications.

Catheter replacement over a guidewire has become an accepted technique for replacing a malfunctioning catheter or exchanging a pulmonary artery catheter for a CVC when invasive monitoring no longer is needed. Catheter insertion over a guidewire is associated with less discomfort and a significantly

lower rate of mechanical complications than are those percutaneously inserted at a new site [135]; in addition, this technique provides a means of preserving limited venous access in some patients. Replacement of temporary catheters over a guidewire in the presence of bacteremia is not an acceptable replacement strategy, because the source of infection is usually colonization of the skin tract from the insertion site to the vein [22, 135]. However, in selected patients with tunneled hemodialysis catheters and bacteremia, catheter exchange over a guidewire, in combination with antibiotic therapy, might be an alternative as a salvage strategy in patients with limited venous access [136–139].

Hemodialysis Catheters

The use of catheters for hemodialysis is the most common factor contributing to bacteremia in dialysis patients [140, 141]. The relative risk for bacteremia in patients with dialysis catheters is sevenfold the risk for patients with primary arteriovenous fistulas [142]. Despite the National Kidney Foundation's effort to reduce the number of hemodialysis patients maintained with catheter access, catheter use increased from 12.7% in 1995 to 22.2% in 1999 [143]. Rates for bacteremia per 100 patient months were 0.2 for arteriovenous fistulas, 0.5 for grafts, 5.0 for cuffed catheters, and 8.5 for noncuffed catheters (CDC, unpublished data, 1999).

To reduce the rate of infection, hemodialysis catheters should be avoided in favor of arteriovenous fistulas and grafts. If temporary access is needed for dialysis, a cuffed catheter is preferable to a noncuffed catheter, even in the ICU setting, if the catheter is expected to stay in place for >3 weeks [11, 144].

Pulmonary Artery Catheters

Pulmonary artery catheters are inserted through a Teflon introducer and typically remain in place an average of 3 days. The majority of pulmonary artery catheters are heparin bonded, which reduces not only catheter thrombosis but also microbial adherence to the catheter [145]. Meta-analysis indicates that standard nonheparin-bonded pulmonary artery catheter rates of CRBSI are 5.5 per 1000 catheter days; for heparin-bonded pulmonary artery catheters, this rate is 2.6 per 1000 catheter days [11]. Because the majority of pulmonary artery catheters are heparin-bonded, the relative risk of infection with these catheters is similar to that of CVC (2.6 versus 2.3 per 1000 catheter days) [11].

A prospective study of 442 pulmonary artery catheters demonstrated an increased risk for CRBSI after 5 days (0/442 CRBSI before 5 days versus 5/442 CSBSI after 5 days; $P < .001$) [146]. A prospective observational study of 71 pulmonary artery catheters demonstrated higher infection rates in catheters left in place longer than 7 days (2% before 7 days versus 16% after 7 days; $P = .056$) [147]. However, no studies indicate that catheter replacement at scheduled time intervals is an effective method to reduce CRBSI [132, 135]. In patients who continue to require hemodynamic monitoring, pulmonary artery catheters do not need to be changed more frequently than every 7 days. No specific recommendation can be made regarding routine replacement of catheters that need to be in place for >7 days.

Pulmonary artery catheters are usually packaged with a thin plastic sleeve that prevents touch contamination when placed over the catheter. In a study of 166 catheters, patients who were randomly assigned to have their catheters self-contained within this sleeve had a reduced risk for CRBSI compared with those who had a pulmonary artery catheter placed without the sleeve ($P = .002$) [148].

Peripheral Arterial Catheters

Peripheral arterial catheters are usually inserted into the radial or femoral artery and permit continuous blood pressure monitoring and blood gas measurements. The rate of CRBSI is comparable to that of temporary CVCs (2.9 versus 2.3 per 1000 catheter days) [11]. One study of peripheral arterial catheters demonstrated no difference in infection rates between changing catheters at scheduled times and changing arterial catheters on an as-needed basis [132]. One observational study of 71 arterial catheters revealed that 10 local infections and four CRBSIs occurred in patients who had peripheral arterial catheters in place for >4 days compared with one local infection and no CRBSIs in patients whose catheters were in place <4 days ($P < .05$) [147]. Because the risk for CRBSI is likely similar to that of short-term CVCs, arterial catheters can be approached in a similar way. No specific recommendation can be made regarding replacement of catheters that need to be in place for >5 days.

Replacement of Administration Sets

The optimal interval for routine replacement of IV administration sets has been examined in three well-controlled studies. Data from each of these studies reveal that replacing administration sets no more frequently than 72 hours after initiation of use is safe and cost-effective [149–151]. Data from a more recent study demonstrated that rates of phlebitis were not substantially different if administration sets were left in place 96 hours compared with 72 hours [128]. When a fluid that enhances microbial growth is infused (e.g., lipid emulsions and blood products), more frequent changes of administration sets are indicated, because these products have been identified as independent risk factors for CRBSI [152–158].

Stopcocks (used for injection of medications, administration of IV infusions, and collection of blood samples) represent a potential portal of entry for microorganisms into vascular access catheters and IV fluids. Stopcock contamination is com-

mon, occurring in 45% and 50% in the majority of series. Whether such contamination is a substantial entry point of CRBSI has been difficult to prove.

"Piggyback" systems are used as an alternative to stopcocks. However, they also pose a risk for contamination of the intravascular fluid if the device entering the rubber membrane of an injection port is exposed to air or comes into direct contact with nonsterile tape used to fix the needle to the port. Modified piggyback systems have the potential to prevent contamination at these sites [159].

Needleless Intravascular Catheter Systems

Attempts to reduce the incidence of sharp injuries and the resultant risk for transmission of bloodborne infections to health-care workers have led to the design and introduction of needleless infusion systems. When the devices are used according to manufacturers' recommendations, they do not substantially affect the incidence of CRBSI [160–167].

Multidose Parenteral Medication Vials

Parenteral medications commonly are dispensed in multidose, parenteral medication vials that might be used for prolonged periods for one or more patients. Although the overall risk for extrinsic contamination of multidose vials is likely minimal [168], the consequences of contamination might result in life-threatening infection [169, 170]. Single-use vials are frequently preservative-free and might pose a risk for contamination if they are punctured several times.

SPECIAL CONSIDERATIONS FOR INTRAVASCULAR CATHETER–RELATED INFECTIONS IN PEDIATRIC PATIENTS

Prevention of CRBSI in children requires additional considerations, although only certain studies have been performed specifically in children. Pediatric data have been derived largely from studies in neonatal or pediatric ICUs and pediatric oncology patients.

Epidemiology

As in adults, the majority of BSIs in children are associated with the use of an intravascular catheter. From 1995 through 2000, the pooled mean catheter-associated BSI rate for all pediatric ICUs reporting data to NNIS was 7.7 per 1000 catheter days [171, 172]. Umbilical catheter and CVC-associated BSI rates for neonatal ICUs ranged from 11.3 per 1000 catheter days in children with birth weight <1000 g to 4.0 per 1000 catheter days in children whose birth weight was >2500 g [171]. Catheter utilization rates were comparable in adult and pediatric ICUs [172, 173].

Microbiology

As in adults, the majority of CRBSIs in children are caused by coagulase-negative staphylococci. During 1992–1999, these bacteria accounted for 37.7% of BSIs in pediatric ICUs reporting to NNIS [12]. Exposure to lipids has been identified as an independent risk factor for development of coagulase-negative staphylococcal bacteremia in very low birth weight infants (i.e., those weighing <1000 g) (odds ratio [OR], 9.4; 95% CI, 1.2–74.2) [155], as well as candidemia in the neonatal ICU (OR, 5.33; 95% CI, 1.23–48.4) [154]. Gram-negative bacteria accounted for 25% of BSIs reported in pediatric ICUs [172], whereas enterococci and *Candida* spp. accounted for 10% and 9%, respectively [172].

Peripheral Venous Catheters

As in adults, the use of peripheral venous catheters in pediatric patients might be complicated by phlebitis, infusion extravasation, and catheter infection [174]. Catheter location, infusion of parenteral nutritional fluids with continuous IV lipid emulsions, and length of ICU stay before catheter insertion have all increased pediatric patients' risk for phlebitis. However, contrary to the risk in adults, the risk for phlebitis in children has not increased with the duration of catheterization [174, 175].

Peripheral Arterial Catheters

In a prospective study of 340 peripheral arterial catheters in children, the following two risk factors for catheter-related infection were identified: (1) use of an arterial system that permitted backflow of blood into the pressure tubing and (2) duration of catheterization [176]. Although a correlation was found between duration of arterial catheterization and risk for catheter colonization, the risk remained constant for 2–20 days at 6.2% [176].

Umbilical Catheters

Although the umbilical stump becomes heavily colonized soon after birth, umbilical-vessel catheterization often is used for vascular access in newborn infants. Umbilical vessels can be cannulated easily and permit both collection of blood samples and measurement of hemodynamic status. The incidences of catheter colonization and BSI are similar for umbilical vein catheters and umbilical artery catheters. In several studies, an estimated 40%–55% of umbilical artery catheters were colonized and 5% resulted in CRBSI; umbilical vein catheters were associated with colonization in 22%–59% of cases [177–179] and with CRBSI in 3%–8% of cases [178]. Although CRBSI rates are similar for umbilical catheters in the high position (i.e., above the diaphragm) compared with the low position (i.e., below the diaphragm and above the aortic bifurcation), catheters placed in the high position result in a lower incidence

of vascular complications without an increase in adverse sequelae [178].

Risk factors for infection differ for umbilical artery and umbilical vein catheters. In one study, neonates with very low birth weight who also received antibiotics for >10 days were at increased risk for umbilical artery CRBSIs [178]. In comparison, those with higher birth weight and receipt of parenteral nutrition fluids were at increased risk for umbilical vein CRBSI. Duration of catheterization was not an independent risk factor for infection of either type of umbilical catheter.

CVCs

Because of the limited vascular sites in children, attention should be given to the frequency with which catheters are replaced in these patients. In a study in which survival analysis techniques were used to examine the relation between the duration of central venous catheterization and complications in pediatric ICU patients, all of the patients studied ($n = 397$) remained uninfected for a median of 23.7 days [180]. In addition, no relation was found between duration of catheterization and the daily probability of infection ($r = 0.21$; $P > .1$), suggesting that routine replacement of CVCs likely does not reduce the incidence of catheter-related infection [180].

Catheter Site Care

Although data regarding the use of the chlorhexidine-impregnated sponge (Biopatch) in children are limited, one randomized, controlled study involving 705 neonates reported a substantial decrease in colonized catheter tips in infants in the Biopatch group compared with the group that had standard dressings (15% versus 24%; RR, 0.6; 95% CI, 0.5–0.9), but no difference in the rates of CRBSI or BSI without a source. Biopatch was associated with localized contact dermatitis in infants of very low birth weight. Of 98 neonates with very low birth weight, 15 (15%) developed localized contact dermatitis; four (1.5%) of 237 neonates weighing >1000 g developed this reaction ($P < .0001$). Infants with gestational age <26 weeks who had CVCs placed at age <8 days were at increased risk for having localized contact dermatitis, whereas no infants in the control group developed this local reaction [181].

Performance Indicators

Performance indicators for reducing CRBSI are (1) implementation of educational programs that include didactic and interactive components for those who insert and maintain catheters; (2) use of maximal sterile barrier precautions during catheter placement; (3) use of chlorhexidine for skin antisepsis; and (4) rates of catheter discontinuation when the catheter is no longer essential for medical management. The impact these recommendations will have on individual institutions should be evaluated using specific performance indicators.

RECOMMENDATIONS FOR PLACEMENT OF INTRAVASCULAR CATHETERS IN ADULTS AND CHILDREN

These recommendations are designed to reduce the infectious complications associated with intravascular catheter use. Recommendations should be considered in the context of the institution's experience with catheter-related infections, experience with other adverse catheter-related complications (e.g., thrombosis, hemorrhage, and pneumothorax), and availability of personnel skilled in the placement of intravascular devices. Recommendations are provided for (1) intravascular catheter use in general; (2) specific devices; and (3) special circumstances (i.e., intravascular-device use in pediatric patients and CVC use for parenteral nutrition and hemodialysis access). Recommendations regarding the frequency of replacing catheters, dressings, administration sets, and fluids also are provided (Appendix B).

As in previous guidelines issued by CDC and HICPAC, each recommendation is categorized on the basis of existing scientific data, theoretical rationale, applicability, and economic impact. The CDC/HICPAC system for categorizing recommendations is as follows:

Category IA. Strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiologic studies.

Category IB. Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies, and a strong theoretical rationale.

Category IC. Required by state or federal regulations, rules, or standards.

Category II. Suggested for implementation and supported by suggestive clinical or epidemiologic studies or a theoretical rationale.

Unresolved issue. Represents an unresolved issue for which evidence is insufficient or no consensus regarding efficacy exists.

I. Health-care worker education and training
   A. Educate health-care workers regarding the indications for intravascular catheter use, proper procedures for the insertion and maintenance of intravascular catheters, and appropriate infection-control measures to prevent intravascular catheter-related infections [39, 43, 45–47, 182–187]. **Category IA**
   B. Assess knowledge of and adherence to guidelines periodically for all persons who insert and manage intravascular catheters [39, 43, 46, 182, 188]. **Category IA**
   C. Ensure appropriate nursing staff levels in ICUs to minimize the incidence of CRBSIs [48, 189, 190]. **Category IB**

II. Surveillance

A. Monitor the catheter sites visually or by palpation through the intact dressing on a regular basis, depending on the clinical situation of individual patients. If patients have tenderness at the insertion site, fever without obvious source, or other manifestations suggesting local or BSI, the dressing should be removed to allow thorough examination of the site [1, 191–193]. **Category IB**

B. Encourage patients to report to their health-care provider any changes in their catheter site or any new discomfort. **Category II**

C. Record the operator, date, and time of catheter insertion and removal, and dressing changes on a standardized form. **Category II**

D. Do not routinely culture catheter tips [8, 194, 195]. **Category IA**

III. Hand hygiene

A. Observe proper hand-hygiene procedures either by washing hands with conventional antiseptic-containing soap and water or with waterless alcohol-based gels or foams. Observe hand hygiene before and after palpating catheter insertion sites, as well as before and after inserting, replacing, accessing, repairing, or dressing an intravascular catheter. Palpation of the insertion site should not be performed after the application of antiseptic, unless aseptic technique is maintained [43, 70, 196–200]. **Category IA**

B. Use of gloves does not obviate the need for hand hygiene [43, 198, 199]. **Category IA**

IV. Aseptic technique during catheter insertion and care

A. Maintain aseptic technique for the insertion and care of intravascular catheters [22, 71, 201, 202]. **Category IA**

B. Wear clean or sterile gloves when inserting an intravascular catheter as required by the Occupational Safety and Health Administration Bloodborne Pathogens Standard. Category IC. Wearing clean gloves rather than sterile gloves is acceptable for the insertion of peripheral intravascular catheters if the access site is not touched after the application of skin antiseptics. Sterile gloves should be worn for the insertion of arterial and central catheters [201, 203]. **Category IA**

C. Wear clean or sterile gloves when changing the dressing on intravascular catheters. **Category IC**

V. Catheter insertion

Do not routinely use arterial or venous cutdown procedures as a method to insert catheters [204–206]. **Category IA**

VI. Catheter site care

A. Cutaneous antisepsis

1. Disinfect clean skin with an appropriate antiseptic before catheter insertion and during dressing changes. Although a 2% chlorhexidine-based preparation is preferred, tincture of iodine, an iodophor, or 70% alcohol can be used [73, 75, 207, 208]. **Category IA**
2. No recommendation can be made for the use of chlorhexidine in infants aged <2 months. **Unresolved issue**
3. Allow the antiseptic to remain on the insertion site and to air dry before catheter insertion. Allow povidone iodine to remain on the skin for at least 2 minutes, or longer if it is not yet dry before insertion [73, 75, 207, 208]. **Category IB**
4. Do not apply organic solvents (e.g., acetone and ether) to the skin before insertion of catheters or during dressing changes [209]. **Category IA**

VII. Catheter-site dressing regimens

A. Use either sterile gauze or sterile, transparent, semipermeable dressing to cover the catheter site [146, 210–212]. **Category IA**

B. Tunneled CVC sites that are well healed might not require dressings. **Category II**

C. If the patient is diaphoretic, or if the site is bleeding or oozing, a gauze dressing is preferable to a transparent, semipermeable dressing [146, 210-212]. **Category II**

D. Replace catheter-site dressing if the dressing becomes damp, loosened, or visibly soiled [146, 210]. **Category IB**

E. Change dressings at least weekly for adult and adolescent patients depending on the circumstances of the individual patient [211]. **Category II**

F. Do not use topical antibiotic ointment or creams on insertion sites (except when using dialysis catheters) because of their potential to promote fungal infections and antimicrobial resistance [107, 213]. **Category IA** (See Central Venous Catheters, Including PICCs, Hemodialysis, and Pulmonary Artery Catheters, in Adult and Pediatric Patients)

G. Do not submerge the catheter under water. Showering should be permitted if precautions can be taken to reduce the likelihood of introducing organisms into the catheter (e.g., if the catheter and connecting device are protected with an impermeable cover during the shower [214, 215]. **Category II**

VIII. Selection and replacement of intravascular catheters

A. Select the catheter, insertion technique, and inser-

tion site with the lowest risk for complications (infectious and noninfectious) for the anticipated type and duration of IV therapy [22, 55, 59, 216–218]. **Category IA**

B. Promptly remove any intravascular catheter that is no longer essential [219, 220]. **Category IA**

C. Do not routinely replace central venous or arterial catheters solely for the purposes of reducing the incidence of infection [134, 135, 221]. **Category IB**

D. Replace peripheral venous catheters at least every 72–96 hours in adults to prevent phlebitis [128]. Leave peripheral venous catheters in place in children until IV therapy is completed, unless complications (e.g., phlebitis and infiltration) occur [174, 175, 222, 223]. **Category IB**

E. When adherence to aseptic technique cannot be ensured (i.e., when catheters are inserted during a medical emergency), replace all catheters as soon as possible and after no longer than 48 hours [22, 71, 201, 202]. **Category II**

F. Use clinical judgment to determine when to replace a catheter that could be a source of infection (e.g., do not routinely replace catheters in patients whose only indication of infection is fever). Do not routinely replace venous catheters in patients who are bacteremic or fungemic if the source of infection is unlikely to be the catheter [224]. **Category II**

G. Replace any short-term CVC if purulence is observed at the insertion site, which indicates infection [224, 225]. **Category IB**

H. Replace all CVCs if the patient is hemodynamically unstable and CRBSI is suspected [224, 225]. **Category II**

I. Do not use guidewire techniques to replace catheters in patients suspected of having catheter-related infection [134, 135]. **Category IB**

IX. Replacement of administration sets (which include the area from the spike of tubing entering the fluid container to the hub of the vascular access device; however, a short extension tube might be connected to the catheter and might be considered a portion of the catheter to facilitate aseptic technique when changing administration sets), needleless systems, and parenteral fluids

A. Administration sets

1. Replace administration sets, including secondary sets and add-on devices, no more frequently than at 72-hour intervals, unless catheter-related infection is suspected or documented [23, 149–151]. **Category IA**
2. Replace tubing used to administer blood, blood products, or lipid emulsions (those combined with amino acids and glucose in a 3-in-1 admixture or infused separately) within 24 hours of initiating the infusion [158, 226–229]. **Category IB**. If the solution contains only dextrose and amino acids, the administration set does not need to be replaced more frequently than every 72 hours [226]. **Category II**
3. Replace tubing used to administer propofol infusions every 6 or 12 hours, depending on its use, per the manufacturer's recommendation [230]. **Category IA**

B. Needleless intravascular devices

1. Change the needleless components at least as frequently as the administration set [160–162, 164–167]. **Category II**
2. Change caps no more frequently than every 72 hours or according to manufacturers' recommendations [160, 162, 165, 166]. **Category II**
3. Ensure that all components of the system are compatible to minimize leaks and breaks in the system [163]. **Category II**
4. Minimize contamination risk by wiping the access port with an appropriate antiseptic and accessing the port only with sterile devices [162, 163, 165]. **Category IB**

C. Parenteral fluids

1. Complete the infusion of lipid-containing solutions (e.g., 3-in-1 solutions) within 24 hours of hanging the solution [156–158, 226, 229]. **Category IB**
2. Complete the infusion of lipid emulsions alone within 12 hours of hanging the emulsion. If volume considerations require more time, the infusion should be completed within 24 hours [156–158]. **Category IB**
3. Complete infusions of blood or other blood products within 4 hours of hanging the blood [231–234]. **Category II**
4. No recommendation can be made for the hang time of other parenteral fluids. **Unresolved issue**

X. IV-injection ports

A. Clean injection ports with 70% alcohol or an iodophor before accessing the system [164, 235, 236]. **Category IA**

B. Cap all stopcocks when not in use [235]. **Category IB**

XI. Preparation and quality control of IV admixtures

A. Admix all routine parenteral fluids in the pharmacy in a laminar-flow hood using aseptic technique [237, 238]. **Category IB**

B. Do not use any container of parenteral fluid that has visible turbidity, leaks, cracks, or particulate matter or if the manufacturer's expiration date has passed [237]. **Category IB**

C. Use single-dose vials for parenteral additives or medications when possible [237, 239]. **Category II**

D. Do not combine the leftover content of single-use vials for later use [237, 239]. **Category IA**

E. If multidose vials are used

1. Refrigerate multidose vials after they are opened if recommended by the manufacturer. **Category II**
2. Cleanse the access diaphragm of multidose vials with 70% alcohol before inserting a device into the vial [236]. **Category IA**
3. Use a sterile device to access a multidose vial and avoid touch contamination of the device before penetrating the access diaphragm [235, 240]. **Category IA**
4. Discard multidose vial if sterility is compromised [235, 240]. **Category IA**

XII. In-line filters

Do not use filters routinely for infection-control purposes [80, 241]. **Category IA**

XIII. IV-therapy personnel

Designate trained personnel for the insertion and maintenance of intravascular catheters [46, 47, 210, 242]. **Category IA**

XIV. Prophylactic antimicrobials

Do not administer intranasal or systemic antimicrobial prophylaxis routinely before insertion or during use of an intravascular catheter to prevent catheter colonization or BSI [97, 98, 108, 243]. **Category IA**

Peripheral Venous Catheters, Including Midline Catheters, in Adult and Pediatric Patients

I. Selection of peripheral catheter

A. Select catheters on the basis of the intended purpose and duration of use, known complications (e.g., phlebitis and infiltration), and experience of individual catheter operators [67, 68, 244]. **Category IB**

B. Avoid the use of steel needles for the administration of fluids and medication that might cause tissue necrosis if extravasation occurs [67, 68]. **Category IA**

C. Use a midline catheter or PICC when the duration of IV therapy will likely exceed 6 days [244]. **Category IB**

II. Selection of peripheral-catheter insertion site

A. In adults, use an upper- instead of a lower-extremity site for catheter insertion. Replace a catheter inserted in a lower-extremity site to an upper-extremity site as soon as possible [67, 245]. **Category IA**

B. In pediatric patients, the hand, the dorsum of the foot, or the scalp can be used as the catheter insertion site. **Category II**

C. Replacement of catheter

1. Evaluate the catheter insertion site daily, by palpation through the dressing to discern tenderness and by inspection if a transparent dressing is in use. Gauze and opaque dressings should not be removed if the patient has no clinical signs infection. If the patient has local tenderness or other signs of possible CRBSI, an opaque dressing should be removed and the site inspected visually. **Category II**
2. Remove peripheral venous catheters if the patient develops signs of phlebitis (e.g., warmth, tenderness, erythema, and palpable venous cord), infection, or a malfunctioning catheter [66]. **Category IB**
3. In adults, replace short, peripheral venous catheters at least 72–96 hours to reduce the risk for phlebitis. If sites for venous access are limited and no evidence of phlebitis or infection is present, peripheral venous catheters can be left in place for longer periods, although the patient and the insertion sites should be closely monitored [66, 128, 246]. **Category IB**
4. Do not routinely replace midline catheters to reduce the risk for infection [131]. **Category IB**
5. In pediatric patients, leave peripheral venous catheters in place until IV therapy is completed, unless a complication (e.g., phlebitis and infiltration) occurs [174, 175, 222, 223]. **Category IB**

III. Catheter and catheter-site care

Do not routinely apply prophylactic topical antimicrobial or antiseptic ointment or cream to the insertion site of peripheral venous catheters [107, 213]. **Category IA**

Central Venous Catheters, Including PICCs, Hemodialysis, and Pulmonary Artery Catheters, in Adult and Pediatric Patients

I. Surveillance

A. Conduct surveillance in ICUs and other patient populations to determine CRBSI rates, monitor trends in those rates, and assist in identifying lapses in infection-control practices [3, 12, 16, 247–250]. **Category IA**

B. Express ICU data as the number of catheter-associated BSIs per 1000 catheter days for both

adults and children and stratify by birth weight categories for neonatal ICUs to facilitate comparisons with national data in comparable patient populations and health-care settings [3, 12, 16, 247–250]. **Category IB**

C. Investigate events leading to unexpected life-threatening or fatal outcomes. This includes any process variation for which a recurrence would likely present an adverse outcome [13]. **Category IC**

II. General principles

A. Use a CVC with the minimum number of ports or lumens essential for the management of the patient [251–254]. **Category IB**

B. Use an antimicrobial or antiseptic-impregnated CVC in adults whose catheter is expected to remain in place >5 days if, after implementing a comprehensive strategy to reduce rates of CRBSI, the CRBSI rate remains above the goal set by the individual institution based on benchmark rates (table 2) and local factors. The comprehensive strategy should include the following three components: educating persons who insert and maintain catheters, use of maximal sterile barrier precautions, and a 2% chlorhexidine preparation for skin antisepsis during CVC insertion [84–86, 90, 91, 255]. **Category IB**

C. No recommendation can be made for the use of impregnated catheters in children. **Unresolved issue**

D. Designate personnel who have been trained and exhibit competency in the insertion of catheters to supervise trainees who perform catheter insertion [39, 43, 46, 182, 187, 188]. **Category IA**

E. Use totally implantable access devices for patients who require long-term, intermittent vascular access. For patients requiring frequent or continuous access, a PICC or tunneled CVC is preferable [256, 257]. **Category II**

F. Use a cuffed CVC for dialysis if the period of temporary access is anticipated to be prolonged (e.g., >3 weeks) [144, 258]. **Category IB**

G. Use a fistula or graft instead of a CVC for permanent access for dialysis [142]. **Category IB**

H. Do not use hemodialysis catheters for blood drawing or applications other than hemodialysis except during dialysis or under emergency circumstances. **Category II**

I. Use povidone-iodine antiseptic ointment at the hemodialysis catheter exit site after catheter insertion and at the end of each dialysis session only if this ointment does not interact with the material of the hemodialysis catheter per manufacturer's recommendation [103, 114, 144]. **Category II**

III. Selection of catheter insertion site

A. Weigh the risk and benefits of placing a device at a recommended site to reduce infectious complications against the risk for mechanical complications (e.g., pneumothorax, subclavian artery puncture, subclavian vein laceration, subclavian vein stenosis, hemothorax, thrombosis, air embolism, and catheter misplacement) [22, 55, 59, 218]. **Category IA**

B. Use a subclavian site (rather than a jugular or a femoral site) in adult patients to minimize infection risk for nontunneled CVC placement [22, 55, 59, 60]. **Category IA**

C. No recommendation can be made for a preferred site of insertion to minimize infection risk for a tunneled CVC [61–63]. **Unresolved issue**

D. Place catheters used for hemodialysis and pheresis in a jugular or femoral vein rather than a subclavian vein to avoid venous stenosis if catheter access is needed [259–263]. **Category IA**

IV. Maximal sterile barrier precautions during catheter insertion

A. Use aseptic technique including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile sheet, for the insertion of CVCs (including PICCS) or guidewire exchange [22, 71]. **Category IA**

B. Use a sterile sleeve to protect pulmonary artery catheters during insertion [148]. **Category IB**

V. Replacement of catheter

A. Do not routinely replace CVCs, PICCs, hemodialysis catheters, or pulmonary artery catheters to prevent catheter-related infections [132, 134, 135]. **Category IB**

B. Do not remove CVCs or PICCs on the basis of fever alone. Use clinical judgment regarding the appropriateness of removing the catheter if infection is evidenced elsewhere or if a noninfectious cause of fever is suspected [224, 264]. **Category II**

C. Guidewire exchange

1. Do not use guidewire exchanges routinely for nontunneled catheters to prevent infection [135, 265]. **Category IB**
2. Use a guidewire exchange to replace a malfunctioning nontunneled catheter if no evidence of infection is present [135, 265]. **Category IB**
3. Use a new set of sterile gloves before handling the new catheter when guidewire exchanges are performed [22, 71]. **Category II**

VI. Catheter and catheter-site care

A. General measures

Designate one port exclusively for hyperalimen-

tation if a multilumen catheter is used to administer parenteral nutrition [266]. **Category II**

B. Antibiotic lock solutions

Do not routinely use antibiotic lock solutions to prevent CRBSI. Use prophylactic antibiotic lock solution only in special circumstances (e.g., in treating a patient with a long-term cuffed or tunneled catheter or port who has a history of multiple CRBSIs despite optimal maximal adherence to aseptic technique) [115, 116, 267, 268]. **Category II**

C. Catheter-site dressing regimens

1. Replace the catheter-site dressing when it becomes damp, loosened, or soiled or when inspection of the site is necessary [65, 146, 211]. **Category IA**
2. Replace dressings used on short-term CVC sites every 2 days for gauze dressings and at least every 7 days for transparent dressings, except in those pediatric patients in which the risk for dis-lodging the catheter outweighs the benefit of changing the dressing [211]. **Category IB**
3. Replace dressings used on tunneled or implanted CVC sites no more than once per week, until the insertion site has healed [211]. **Category IB**
4. No recommendation can be made regarding the necessity for any dressing on well-healed exit sites of long-term cuffed and tunneled CVCs. **Unresolved issue**

D. No recommendation can be made for the use of chlorhexidine sponge dressings to reduce the incidence of infection. **Unresolved issue**

E. Do not use chlorhexidine sponge dressings in neonates aged <7 days or of gestational age <26 weeks [181]. **Category II**

F. No recommendation can be made for the use of sutureless securement devices. **Unresolved issue**

G. Ensure that catheter-site care is compatible with the catheter material [109, 110]. **Category IB**

H. Use a sterile sleeve for all pulmonary artery catheters [148]. **Category IB**

Additional Recommendations for Peripheral Arterial Catheters and Pressure Monitoring Devices for Adult and Pediatric Patients

I. Selection of pressure monitoring system

Use disposable, rather than reusable, transducer assemblies when possible [269–273]. **Category IB**

II. Replacement of catheter and pressure monitoring system

A. Do not routinely replace peripheral arterial catheters to prevent catheter-related infections [132, 147, 221, 274]. **Category II**

B. Replace disposable or reusable transducers at 96-hour intervals. Replace other components of the system (including the tubing, continuous-flush device, and flush solution) at the time the transducer is replaced [22, 270]. **Category IB**

III. Care of pressure monitoring systems

A. General measures

1. Keep all components of the pressure monitoring system (including calibration devices and flush solution) sterile [269, 275–277]. **Category IA**
2. Minimize the number of manipulations of and entries into the pressure monitoring system. Use a closed-flush system (i.e., continuous flush), rather than an open system (i.e., one that requires a syringe and stopcock), to maintain the patency of the pressure monitoring catheters [272, 278]. **Category II**
3. When the pressure monitoring system is accessed through a diaphragm rather than a stopcock, wipe the diaphragm with an appropriate antiseptic before accessing the system [272]. **Category IA**
4. Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit [272, 279, 280]. **Category IA**

B. Sterilization or disinfection of pressure monitoring systems

1. Use disposable transducers [272, 279–282]. **Category IB**
2. Sterilize reusable transducers according to the manufacturers' instructions if the use of disposable transducers is not feasible [272, 279–282]. **Category IA**

Recommendations for Umbilical Catheters

I. Replacement of catheters

A. Remove and do not replace umbilical artery catheters if any signs of CRBSI, vascular insufficiency, or thrombosis are present [283]. **Category II**

B. Remove and do not replace umbilical venous catheters if any signs of CRBSI or thrombosis are present [283]. **Category II**

C. No recommendation can be made for treating through an umbilical venous catheter suspected of being infected. **Unresolved issue**

D. Replace umbilical venous catheters only if the catheter malfunctions. **Category II**

II. Catheter-site care

A. Cleanse the umbilical insertion site with an antisep-

tic before catheter insertion. Avoid tincture of iodine because of the potential effect on the neonatal thyroid. Other iodine-containing products (e.g., povidone-iodine) can be used [75, 177, 178, 284, 285]. **Category IB**

B. Do not use topical antibiotic ointment or creams on umbilical catheter insertion sites because of the potential to promote fungal infections and antimicrobial resistance [107, 213]. **Category IA**

C. Add low doses of heparin (0.25–1.0 F/mL) to the fluid infused through umbilical arterial catheters [286–288]. **Category IB**

D. Remove umbilical catheters as soon as possible when no longer needed or when any sign of vascular insufficiency to the lower extremities is observed. Optimally, umbilical artery catheters should not be left in place >5 days [283, 289]. **Category II**

E. Umbilical venous catheters should be removed as soon as possible when no longer needed but can be used up to 14 days if managed aseptically [290, 292, 293]. **Category II**

DISCLOSURE OF FINANCIAL INTERESTS OR RELATIONSHIPS

Dennis Maki. Research grant sponsorship from Arrow, 3M, Becton-Dickinson, Johnson & Johnson; consultant for Micrologix.

Issam Raad. Holds 2 patents associated with minocycline-rifampin catheters. Patents are the property of University of Texas M. D. Anderson Cancer Center, Baylor College of Medicine, and Wake Forest University. Both patents are licensed to Cook Critical Care, with royalty rights to the institutions involved, and a percentage of royalties to the inventors. Co-inventor of patents associated with minocycline-EDTA flush solution. These patents are not yet licensed. Becton-Dickinson holds rights to this technology. Grant and research support from Kimberly Clark, Becton-Dickinson. Abbott Labs, Immunomedics, and Cook Critical Care.

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APPENDIX A

EXAMPLES OF CLINICAL DEFINITIONS FOR CATHETER-RELATED INFECTIONS

LOCALIZED CATHETER COLONIZATION

Significant growth of a microorganism (>15 CFU) from the catheter tip, subcutaneous segment of the catheter, or catheter hub.

EXIT SITE INFECTION

Erythema or induration within 2 cm of the catheter exit site, in the absence of concomitant bloodstream infection (BSI) and without concomitant purulence.

CLINICAL EXIT SITE INFECTION (OR TUNNEL INFECTION)

Tenderness, erythema, or site induration >2 cm from the catheter site along the subcutaneous tract of a tunneled (e.g., Hickman or Broviac) catheter, in the absence of concomitant BSI.

POCKET INFECTION

Purulent fluid in the subcutaneous pocket of a totally implanted intravascular catheter that might or might not be associated with spontaneous rupture and drainage or necrosis of the overlaying skin, in the absence of concomitant BSI.

INFUSATE-RELATED BSI

Concordant growth of the same organism from the infusate and blood cultures (preferably percutaneously drawn) with no other identifiable source of infection.

CATHETER-RELATED BSI

Bacteremia/fungemia in a patient with an intravascular catheter with at least one positive blood culture obtained from a peripheral vein, clinical manifestations of infections (i.e., fever, chills, and/or hypotension), and no apparent source for the BSI except the catheter. One of the following should be present: a positive semiquantitative (>15 CFU/catheter segment) or quantitative (>103 CFU/catheter segment catheter) culture whereby the same organism (species and antibiogram) is isolated from the catheter segment and peripheral blood; simultaneous quantitative blood cultures with a >5:1 ratio CVC versus peripheral; differential period of CVC culture versus peripheral blood culture positivity of >2 hours.

SURVEILLANCE DEFINITIONS FOR PRIMARY BSIS, NATIONAL NOSOCOMIAL INFECTIONS SURVEILLANCE SYSTEM

LABORATORY-CONFIRMED BSI

Should meet at least one of the following criteria:

Criterion 1. Patient has a recognized pathogen cultured from one or more blood cultures, and the pathogen cultured from the blood is not related to an infection at another site.

Criterion 2. Patient has at least one of the following signs or symptoms: fever (>100.4°F [>38°C]), chills, or hypotension, and at least one of the following:

1. Common skin contaminant (e.g., diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci) cultured from two or more blood cultures drawn on separate occasions.

2. Common skin contaminant (e.g., diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci) cultured from at least one blood culture from a patient with an intravenous line, and the physician institutes appropriate antimicrobial therapy.

3. Positive antigen test on blood (e.g., *Haemophilus influenzae, Streptococcus pneumoniae, Neisseria meningitides,* or group B streptococcus).

and signs and symptoms with positive laboratory results are not related to an infection at another site.

Criterion 3. Patient aged <1 year has at least one of the following signs or symptoms: fever (>100.4°F [>38°C]), hypothermia (<98.6°F [<37°C]), apnea, or bradycardia, and at least one of the following:

1. Common skin contaminant (e.g., diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci) cultured from two or more blood cultures drawn on separate occasions.

2. Common skin contaminant (e.g., diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci) cultured from at least one blood culture from a patient with an intravenous line, and the physician institutes appropriate antimicrobial therapy.

3. Positive antigen test on blood (e.g., *Haemophilus influenzae, Streptococcus pneumoniae, Neisseria meningitides,* or group B streptococcus).

and signs and symptoms with positive laboratory results are not related to an infection at another site.

CLINICAL SEPSIS

Should meet at least one of the following criteria:

Criterion 1. Patient has at least one of the following clinical signs with no other recognized cause: fever (>100.4°F [>38°C]), hypotension (systolic pressure <90 mm Hg), or oliguria (<20 mL/hr), and blood culture not done or no organisms or antigen detected in blood and no apparent infection at another site, and physician institutes treatment for sepsis.

Criterion 2. Patient aged <1 year has at least one of the following clinical signs or symptoms with no other recognized cause: fever (>100.4°F [>38°C]), hypothermia (<98.6°F [<37°C]), apnea, or bradycardia, and blood culture not done or no organisms or antigen detected in blood and no apparent infection at another site, and physician institutes treatment for sepsis.

CATHETER-ASSOCIATED BSI

Defined by the following:

∗ Vascular access device that terminates at or close to the heart or one of the great vessels. An umbilical artery or vein catheter is considered a central line.

∗ BSI is considered to be associated with a central line if the line was in use during the 48-hour period before development of the BSI. If the time interval between onset of infection and device use is >48 hours, there should be compelling evidence that the infection is related to the central line.

ARTERIAL OR VENOUS INFECTION

Included are arteriovenous graft, shunt, fistula, or intravenous cannulation. Should meet at least one of the following criteria:

Criterion 1. Patient has organisms cultured from arteries or veins removed during a surgical operation and blood culture not done or no organisms cultured from blood.

Criterion 2. Patient has evidence of arterial or venous infection seen during a surgical operation or histopathologic examination.

Criterion 3. Patient has at least one of the following signs or symptoms with no other recognized cause: fever (>100.4°F [>38°C]), pain, erythema, or heat at involved vascular site and >15 CFUs cultured from an intravascular cannula tip using a semiquantitative culture method and blood culture not done or no organisms cultured from blood.

Criterion 4. Patient has purulent drainage at the involved vascular site and blood culture not done or no organisms cultured from blood.

Criterion 5. Patient aged <1 year has at least one of the following signs or symptoms with no other recognized cause: fever (>100.4°F [>38°C]), hypothermia (<98.6°F [<37°C]), apnea, bradycardia, lethargy, or pain, erythema or heat at involved vascular site and >15 colonies cultured from intravascular cannula tip using semiquantitative method and blood culture not done or no organisms cultured from blood.

APPENDIX B

Table B1. Summary of recommended frequency of replacements for catheters, dressings, administration sets, and fluids.

Catheter	Replacement and relocation of device	Replacement of catheter site dressing	Replacement of administration sets	Hang time for parenteral fluids
Peripheral venous catheters	In *adults,* replace catheter and rotate site no more frequently than every 72–96 hours. Replace catheters inserted under emergency basis and insert a new catheter at a different site within 48 hours. In *pediatric* patients, do not replace peripheral catheters unless clinically indicated.	Replace dressing when the catheter is removed or replaced, or when the dressing becomes damp, loosened, or soiled. Replace dressings more frequently in diaphoretic patients. In patients who have large bulky dressings that prevent palpation or direct visualization of the catheter insertion site, remove the dressing and visually inspect the catheter at least daily and apply a new dressing.	Replace intravenous tubing, including add-on devices, no more frequently than at 72-hour intervals unless clinically indicated. Replace tubing used to administer blood, blood products, or lipid emulsions within 24 hours of initiating the infusion. *No recommendation* for replacement of tubing used for intermittent infusions. Consider short extension tubing connected to the catheter to be a portion of the device. Replace such extension tubing when the catheter is changed.	*No recommendation* for the hang time of intravenous fluids, including nonlipid-containing parenteral nutrition fluids. Complete infusion of lipid-containing parenteral nutrition fluids (e.g., 3-in-1 solutions) within 24 hours of hanging the fluid. Complete infusion of lipid emulsions alone within 12 hours of hanging the fluid. Complete infusions of blood products within 4 hours of hanging the product.
Midline catheters	*No recommendation* for the frequency of the catheter replacement.	As above.	As above.	As above.
Peripheral arterial catheters	In *adults*, do not replace catheters routinely to prevent catheter-related infection. In *pediatric* patients, *no recommendation* for the frequency of catheter replacement. Replace disposable or reusable transducers at 96-hour intervals. Replace continuous flush device at the time the transducer is replaced.	Replace dressing when the catheter is replaced, or when the dressing becomes damp, loosened, or soiled, or when inspection of the site is necessary.	Replace the intravenous tubing at the time the transducer is replaced (i.e., 96-hour intervals).	Replace the flush solution at the time the transducer is replaced (i.e., 96-hour intervals).
Central venous catheters including peripherally inserted central catheters and hemodialysis catheters[a]	Do not routinely replace catheters.	Replace gauze dressings every 2 days and transparent dressings every 7 days on short-term catheters. Replace the dressing when the catheter is replaced, or when the dressing becomes damp, loosened, or soiled, or when inspection of the site is necessary.	Replace intravenous tubing and add-on devices no more frequently than at 72-hour intervals. Replace tubing used to administer blood products or lipid emulsions within 24 hours of initiating the infusion.	*No recommendation* for the hang time of intravenous fluids, including nonlipid-containing parenteral nutrition fluids. Complete infusions of lipid-containing fluids within 24 hours of hanging the fluid.
Pulmonary artery catheters	Do not replace catheter to prevent catheter related infection.	As above.	As above.	As above.
Umbilical catheters	Do not routinely replace catheters.	Not applicable.	Replace intravenous tubing and add-on devices no more frequently than at 72-hour intervals. Replace tubing used to administer blood products or lipid emulsions within 24 hours of initiating the infusion.	*No recommendation* for the hang time of intravenous fluids, including nonlipid-containing parenteral nutrition fluids. Complete infusion of lipid-containing fluids within 24 hours of hanging the fluid.

[a] Includes nontunneled catheters, tunneled catheters, and totally implanted devices.

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