Draft Guideline For The Prevention Of Intravascular Catheter-Related Infections

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Preface

The "Guideline for Prevention of Intravascular Catheter Related Infections" provides healthcare practitioners with background information and specific recommendations to reduce the incidence of intravascular catheter-related bloodstream infections (CR-BSI). This guideline replaces the "Guideline for Prevention of Intravascular Device-Related Infections" published in 1996 [1].

Part I of this current document (Intravascular Catheter-Related Infections: An Overview) reviews important issues in intravascular catheter use and maintenance. These issues include definitions and diagnosis of catheter-related infection, barrier precautions during catheter insertion, skin antisepsis, intervals for replacement of catheters and intravenous (IV) fluids and administration sets, catheter site care, the role of specialized intravascular catheter personnel, and the use of antimicrobial/antiseptic-impregnated catheters, prophylactic systemic antibiotics, flush solutions, and anticoagulants. Part II (Recommendations for Prevention of Intravascular Catheter- Related Infections) provides consensus recommendations of the Healthcare Infection Control Practices Advisory Committee (HICPAC) and other professional societies.

This document was prepared by a working group composed of members from professional organizations (listed as sponsors or endorsing organizations) representing the disciplines of critical care medicine, infectious diseases, healthcare infection control, surgery, anesthesiology, interventional radiology, pulmonary medicine, pediatrics, and nursing. The working group was led by the Society of Critical Care Medicine (SCCM). The active participation and endorsement of multiple professional societies has reduced the confusion and redundancy that can occur when different disciplines provide conflicting or inconsistent recommendations or guidelines to healthcare providers.

The "Guideline for Prevention of Intravascular Catheter-Related Infections" has been developed for practitioners who insert catheters and for personnel who are responsible for surveillance and control of infections in the hospital setting as well as in the outpatient and home healthcare setting. Most recommendations are appropriate for the inpatient, outpatient, and home care setting, unless otherwise noted.

PART I: INTRAVASCULAR CATHETER-RELATED INFECTIONS IN ADULT AND PEDIATRIC PATIENTS: AN OVERVIEW

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

       Healthcare institutions purchase millions of intravascular catheters each year. The incidence of CR-BSI varies considerably with the type of catheter, frequency of catheter manipulation, and patient-related factors such as underlying disease and acuity of illness. Peripheral venous catheters are the most frequently used venous access devices. While the incidence of local or bloodstream infections assoxiated with peripheral venous catheters is usually low, serious infectious complications are recognized by clinicians because of the large numbers of such catheters that are placed. Most serious catheter-related infections, however, are associated with central venous catheters (CVCs), especially those that are placed in patients in the ICU. 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 may be needed for extended periods of time, patients may be colonized with hospital acquired organisms, and the catheter may be manipulated multiple times per day for the administration of fluids, drugs, and blood products. Moreover, some catheters may be inserted in urgent situations during which optimal attention to aseptic technique may not be feasible. Certain catheters such as pulmonary artery catheters and peripheral arterial catheters may 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 due to infectious complications has been estimated in several studies [2-5]. One study estimated that there are 15 million CVC days per year in ICUs alone in the United States [2]. If, on average, the rate of CVC associated blood stream infections is 5.3 per 1000 catheter days in the ICU [3], approximately 80,000 CVC-associated BSIs occur in ICUs each year in the United States. Thus, it would appear that 9600-20,000 patients per year die in ICUs in the United States due to catheter-associated BSI. The attributable mortality for these BSIs has ranged from 12-25% in prospective studies [4, 5], and the attributable cost per infection has been estimated to be $3,700-$29,000 [5, 6]. The annual cost of caring for patients with CVC-associated BSIs is between $296 million and $2.3 billion [7].

       An analysis by Kluger and Maki has suggested that a total of 250,000 cases of CVC-associated BSIs occur annually if one assesses the entire hospital rather than focusing exclusively on the ICU. They estimated 12-25% attributable mortality for each infection and a marginal cost to the healthcare system of $25,000 per episode [8].

       Thus, by a variety of analyses, the cost of CVC-associated BSI is substantial both in terms of morbidity and in terms of financial resources expended. The data are compelling that a major effort is warranted to implement strategies to reduce the incidence of these infections if we are to improve patient outcome and reduce healthcare costs. This effort must be multidisciplinary, involving healthcare professionals who insert and maintain intravascular catheters, healthcare managers who allocate resources, and patients who are capable of assisting in the care of their catheters.

Terminology and Estimates of Risk

The terminology to identify catheters is confusing because many clinicians and authors use one aspect of the catheter for informal reference. A catheter may be designated by the type of vessel it occupies (peripheral venous, central venous, or arterial); its intended life span (temporary or short-term, such as less than 30 days vs. permanent or long-term, such as more than 30 days); its site of insertion (subclavian, femoral, internal jugular, peripheral, peripherally inserted central catheter (PICC)); its pathway from skin to vessel (tunneled vs. non-tunneled); its physical length (long vs. short); or some special characteristic of the catheter (presence or absence of a cuff, impregnation with heparin, antibiotics or antiseptics, or the number of lumens). To accurately identify a catheter, all of these aspects must be described. Table 1 provides a summary of terminology, along with some of the unique characteristics of catheters.

The rate of all catheter-related infections (i.e., local infections and systemic infections in which no blood culture was positive, as well as CR-BSI) is difficult to determine since most surveillance systems capture only catheter-associated BSIs and do not enumerate local infections. CR-BSI is an ideal parameter to follow since it represents the most serious form of catheter-related infection. However, the rate of such infection depends on how CR-BSI is defined. Healthcare professionals must recognize the difference between surveillance definitions and more precise and specific clinical definitions. As indicated in Appendix 1, the surveillance definitions for catheter associated BSI includes all BSIs that occur in patients with CVCs, when other sites of infection have been excluded. That is, the surveillance definition overestimates the true incidence of CR-BSI because not all BSIs originate from a catheter. Some bacteremias are secondary BSIs from undocumented sources such as post-operative 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 a significant number of colonies of an organism identical to the bloodstream isolate. That is, such a clinical definition would focus on catheter-**related** BSIs. Therefore, when comparing a healthcare facility's infection rate to published data, it is crucial to ascertain that one is using a comparable definition if one is to accurately compare one's data to a benchmark.

The Centers for Disease Control and Prevention and the Joint Commission on Accreditation of Healthcare Organizations both recommend that the risk of catheter associated BSIs be expressed as number of catheter associated BSIs per 1000 CVC days (catheter days are the total number of days of exposure to CVCs, i.e. one catheter in place for one day=one catheter-day; two catheters in place for one day=one catheter day) [9, 10].This parameter is more useful than the rate expressed as the number of catheter-associated infections per 100 catheters (or percent of catheters studied), because it accounts for BSIs over time and therefore adjusts risk for the number of days the catheter is in use.

EPIDEMIOLOGY AND MICROBIOLOGY

Since 1970, the CDC's National Nosocomial Infection Surveillance System (NNIS) has been collecting data on incidence and etiologies of hospital-acquired infections, including CVC-associated BSIs in a group of almost 300 hospitals nationwide. Most 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. For1995-2000, the NNIS hospitals reported ICU rates of CVC-associated BSI ranging from 2.8 (cardiothoracic ICU) to 10.0 (burn ICU) BSIs per 1000 central catheter days (Table 2) [11].

The relative risk of intravascular catheter-associated BSI has also been assessed in a meta-analysis of 223 prospective studies in adult patients [8]. Relative risk of infection was best appreciated by analyzing rates of infection both by BSIs per 100 catheters (%) and BSIs per 1000 catheter days. These rates, and the NNIS-derived data, are important benchmarks for individual hospitals to use to estimate how their rates compare to other institutions. Rates are influenced by patient-related parameters, such as severity of illness and type of illness (e.g., third-degree burns vs. post-cardiac surgery), and by catheter related parameters, such as the condition under which the catheter was placed (e.g., elective vs. urgent) and catheter type (e.g., tunneled vs. nontunneled, or subclavian vs. jugular).

Types of organisms that most commonly cause hospital-acquired BSIs have been changing. Between 1986 and 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) [12]. Pooled data from 1992-1999 indicate that coagulase-negative staphylococci followed by enterococci are now the most frequently isolated causes of hospital-acquired BSIs [9]. Coagulase-negative staphylococci account for 37 % [9] and *S. aureus* account for 12.6% of reported hospital-acquired BSIs [9]. Also notable was the susceptibility pattern of the *S. aureus* isolates. In 1999, for the first time since NNIS has been reporting susceptibilities, more than 50% of all *S. aureus* ICU isolates were oxacillin resistant [9].

Enterococci accounted for 13.5% of BSIs, an increase from 8% reported to NNIS from 1986 through 1989. There has also been a dramatic rise in enterococcal ICU isolates resistant to vancomycin, escalating from 0.5% in 1989 to 25.9% in 1999 [9].

Candida spp. caused 8% of hospital-acquired BSIs reported to NNIS during 1986-1989 [12, 13] and 1992-1999 [9, 14, 15]. Resistance of *Candida* spp. to commonly used antifungal agents has become a clinically important issue. While NNIS has not reported the fraction of BSIs due to non-albicans species or fluconazole susceptibility data, other epidemiological and clinical data document that fluconazole resistance is an increasingly relevant consideration when designing empiric therapeutic regimens for CR-BSIs due to 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 [14]. Additionally, 48% of *Candida* BSIs were caused by non-albicans species, including *C. glabrata* and *C. krusei,* which are more likely than *C. albicans* to demonstrate resistance to fluconazole and itraconazole [15, 16].

Gram-negative bacilli accounted for 19% of catheter-associated BSIs between 1986 and 1989 [12] compared to 14% of catheter-associated BSIs between 1992-1999 [9]. An increasing fraction of ICU-related isolates are caused by *Enterobacteriaceae* -producing extended-spectrum β-lactamases (ESBLs), particularly *Klebsiella pneumoniae* [17]. Such organisms are resistant to many commonly used cephalosporins.

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 [18, 19]. Contamination of the catheter hub is an important contributor to intraluminal colonization of long-term catheters [20-22]. Occasionally, catheters may become hematogenously seeded from another focus of infection. Rarely, infusate contamination leads to CR-BSI [23].

Important pathogenic determinants of catheter-related infection are (1) the material of which the device is made and (2) the virulence of the infecting organism. In vitro studies show that catheters made of polyvinyl chloride or polyethylene appear to be less resistant to the

adherence of microorganisms than are catheters made of Teflon, silicone elastomer, or polyurethane [24, 25]. Thus, most 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*) [26-28]. Thus catheters made of certain materials may be especially vulnerable to microbial colonization and subsequent infection. Additionally, certain catheter materials are more thrombogenic than others, a characteristic that also may predispose to catheter colonization and catheter-related infection [28, 29]. This association has led to emphasis on preventing catheter-related thrombus as an additional mechanism for reducing CR-BSI.

The adherence properties of a given microorganism are also important in the pathogenesis of catheter-related infection. For example, *S. aureus* can adhere to host proteins (e.g., fibronectin) commonly present on catheters [30, 31]. Also, coagulase-negative staphylococci adhere to polymer surfaces more readily than do other pathogens such as *Escherichia coli* or *S. aureus*. Additionally, certain strains of coagulase-negative staphylococci produce an extracellular polysaccharide often referred to as "slime" [32, 33]. 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) [34]. Certain *Candida* spp., in the presence of glucose-containing fluids, may produce slime similar to that of their bacterial counterparts, potentially explaining the increased proportion of BSIs due to fungal pathogens among patients receiving parenteral nutrition fluids [35].

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

Quality Assurance and Continuing Education

Measures to minimize the risk of infection associated with intravascular therapy must strike a balance between patient safety and cost effectiveness. As knowledge, technology, and healthcare settings change, infection control and prevention measures must change. This implies the need for well-organized programs that provide, monitor, and evaluate care and provide education to all caregivers. Reports spanning the past two decades have consistently found that risk of infection declines following standardization of aseptic care [36-39] and that insertion and maintenance of intravascular catheters by inexperienced staff may increase the risk of catheter colonization and CR-BSI [40]. Specialized "IV teams" have shown unequivocal effectiveness in reducing the incidence of catheter-related infections and associated complications and costs [41-44]. Additionally, infection risk increases with nursing staff reductions below a critical level [45].

Site of Catheter Insertion

The site at which a catheter is placed influences the subsequent risk of catheter-related infection and phlebitis. The influence of site on the risk for catheter infections is related in part to the risk of 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 of infection than are upper extremity sites [46-

48]. In addition, hand veins have a lower risk of phlebitis than do veins on the wrist or upper arm [49].

The density of skin flora at the catheter insertion site is a major risk factor for CR-BSI. Many authorities recommend that central catheters be placed in a subclavian site in preference to a jugular or femoral site to reduce the risk of infection. No randomized trial has satisfactorily compared infection rates for catheters placed in jugular, subclavian, and femoral sites. Catheters inserted into an internal jugular vein were associated with higher risk of infection than were those inserted into a subclavian or femoral vein in observational studies and in one prospective study [19, 50, 51].

Regarding femoral catheters, several investigations have suggested that such catheters have a relatively high colonization rate [52]. Femoral catheters are usually avoided if possible because they are associated with a higher risk of deep venous thrombosis than are internal jugular or subclavian catheters [53-56], and because of a presumption that such catheters are more likely to become infected, particularly in children with diapers and incontinent adults.

Thus, a subclavian site is preferred for infection control purposes, although other considerations such as the potential for mechanical complications, risk of subclavian vein stenosis, and operator skill must enter into the ultimate decision about where to place the catheter. Consideration of comfort, security, and maintenance of asepsis as well as patient-specific factors (e.g., preexisting catheters, anatomic deformity, bleeding diathesis), relative risk of mechanical complications (e.g., bleeding, pneumothorax), and the risk of infection should guide site selection.

Type of Catheter Material

As indicated above in the section on pathogenesis, Teflon or polyurethane catheters appear to be associated with fewer infectious complications than catheters made of polyvinyl chloride or polyethylene [24, 57, 58]. Steel needles used as an alternative to catheters for peripheral venous access have the same rate of infectious complications as do Teflon catheters [59, 60]. However, the use of steel needles frequently is complicated by infiltration of IV fluids into the subcutaneous tissues, a potentially serious complication if the infused fluid is a vesicant [60].

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. Hand hygiene may utilize either an alcohol-based product [61] or an antibacterial soap with adequate rinsing [62]. Appropriate aseptic technique does not necessarily require sterile gloves: a new pair of disposable non-sterile gloves may be used in conjunction with a "no-touch" technique for the insertion of peripheral venous catheters. However, gloves are recommended as standard precautions for the prevention of bloodborne pathogen exposure.

Compared to peripheral venous catheters, CVCs carry a significantly greater risk of infection, and the level of barrier precautions needed to prevent infection during insertion of CVCs should therefore be more stringent. Full barrier precautions (cap, mask, sterile gown, sterile gloves, large sterile drape) during the insertion of CVCs reduce the incidence of CR-BSI compared to standard precautions (sterile gloves and small drapes) [19, 63]. The efficacy of such precautions for insertion of PICCs and midline catheters has not been studied, but it is reasonable to extrapolate the use of maximal barrier precautions to PICCs.

Skin Antisepsis

In the United States, povidone iodine is the most widely used antiseptic for cleansing arterial catheter and central catheter insertion sites [64]. However, preparation of central venous and arterial sites with 2% chlorhexidine gluconate has been shown to lower BSI rates compared to site preparation with 10% povidone-iodine or 70% alcohol [65]. However, tincture of chlorhexidine gluconate 0.5% has not been shown to be more effective than 10% povidone iodine in adults. A prospective randomized study comparing 0.5% chlorhexidine gluconate to povidone iodine showed no difference in preventing CR-BSI or CVC colonization in adults [66]. In neonates, however, 0.5% chlorhexidine reduced peripheral IV colonization compared to povidone iodine (20/418 vs. 38/408 catheters; $p = 0.01$) [67]. The study was not powered to assess differences in CR-BSI rates.

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, thus saving personnel time.

In the largest controlled trial of dressing regimens on peripheral catheters to date, Maki and Ringer examined the infectious morbidity associated with the use of transparent dressings on more than 2,000 peripheral catheters [57]. Their findings 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 there are no clinically important differences 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 of thrombophlebitis [57].

Regarding CVC dressings, a meta-analysis has assessed studies that compared the risk of catheter-related BSIs for groups using transparent dressings versus groups using gauze dressing [68]. The risk for CR-BSIs did not differ between the groups. The choice of dressing may be a matter of preference. If blood is oozing from the catheter insertion site, gauze dressing may be preferred.

A chlorhexidine-impregnated sponge (Biopatch) placed over the site of short-term arterial and CVCs reduced the risk of catheter colonization and CR-BSI in a multi-center study [69]. There were no adverse systemic effects from using this device. Routine use of chlorhexidine–impregnated sponges may reduce the risk of CR-BSI in adult and adolescent patients with short-term catheters, particularly with uncuffed CVCs and arterial catheters.

In-line filters

In-line filters reduce the incidence of infusion-related phlebitis [70, 71]. There are no data to support their efficacy in preventing infections associated with intravascular catheters and infusion systems. Proponents of filters cite a number of potential benefits: (1) reducing the risk of infection from contaminated infusate or proximal contamination (i.e., introduced proximal to the filter); (2) reducing the risk of 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 may contaminate IV fluids [72] and (4) filtering endotoxin produced by gram-negative organisms in contaminated infusate [73]. These theoretical advantages must 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 most particulates. Furthermore, in-line filters may become blocked, especially with certain solutions (i.e., dextran, lipids, mannitol), thereby increasing the number of line manipulations and decreasing the availability of administered drugs [74]. Thus, for the purposes of reducing the risk for CR-BSI, no strong recommendation can be made in favor of using in-line filters.

Antimicrobial/antiseptic impregnated catheters and cuffs

Certain antimicrobial or antiseptic impregnated or coated catheters and cuffs can decrease the risk of CR-BSI in selected patient populations and potentially decrease hospital costs associated with treating CR-BSIs, despite the additional cost of an antimicrobial/antiseptic impregnated catheter [75]. 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 less than 30 days. And although all of the studies have been conducted in adults, these catheters have been approved by the FDA for marketing in patients as small as 3 kg. There are no antiseptic or antimicrobial impregnated catheters currently available for neonates.

Chlorhexidine/silver sulfadiazine. Catheters coated with chlorhexidine/silver sulfadiazine only on the external luminal surface have been studied as a means to reduce CR-BSI. Two meta-analyses [2, 76] demonstrated that such catheters reduced the risk for CR-BSI compared to standard noncoated catheters. The mean duration of catheter placement in one meta-analysis ranged between 5.1 and 11.2 days [77]. The half-life of antimicrobial activity against *S. epidermidis* is 3 days in vitro for catheters coated with chlorhexidine/silver sulfadiazine, and the antimicrobial activity decreases over time [78]. The benefit for the patients who receive these catheters will be realized within the first 14 days [77]. Although rare, anaphylaxis has been reported with the use of these chlorhexidine/silver sulfadiazine catheters in Japan [79]. Whether patients will become colonized or infected with organisms resistant to chlorhexidine/silver sulfadiazine remains to be determined [77].

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 [80] in settings in which the risk of CR-BSI is high despite the adherence to other preventive strategies such as maximal barrier precautions and aseptic technique. Use of these catheters may be cost effective in ICU patients, burn patients, neutropenic patients and patients who have had catheters placed under emergency conditions.

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 CR-BSI when compared with chlorhexidine-silver sulfadiazine impregnated catheters [81]. The beneficial effect began after day 5 of catheterization. None of the catheters were evaluated beyond 30 days. No minocycline/rifampin-resistant organisms were reported. However, based on in vitro data, there is concern that these impregnated catheters could increase the incidence of minocycline and rifampin resistance among important pathogens, especially staphylococci. The half-life of antimicrobial activity against *S. epidermidis* is 25 days with catheters coated with minocycline/rifampin, compared to 3 days for catheters coated with chlorhexidine/silver sulfadiazine in vitro [78]. In vivo, the duration of antimicrobial activity of the minocycline/rifampin catheter is longer than that of the chlorhexidine/silver sulfadiazine catheter [81]. As with chlorhexidine/silver sulfadiazine catheters, some clinicians have recommended that the minocycline/rifampin catheters be considered in patient populations when the rate of CR-BSI exceeds 3.3 per 1000 catheter days [77]. Others suggest that reducing all rates of CR-BSI should be the goal [82]. The decision to use chlorhexidine/silver sulfadiazine or minocycline/rifampin impregnated catheters should be based on the need to enhance prevention of CR-BSI 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 CR-BSI. A combination platinum/silver impregnated catheter is available in Europe and has recently been approved by the FDA for use in the United States. Although these catheters are being marketed for their antimicrobial properties, no published studies support a recommendation for their use to prevent CR-BSI.

Silver cuffs. Ionic silver has been used in subcutaneous collagen cuffs attached to CVCs [83].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 or longer, the cuff failed to reduce the incidence of CR-BSI [84, 85]. Two other studies of short-term catheters could not demonstrate efficacy because of the small number of CR-BSI observed [83, 86].

Systemic Antibiotic Prophylaxis

There is no evidence that oral or parenteral antibacterial or antifungal drugs can reduce the incidence of CR-BSI among adults [87-89]. However, among low birth-weight infants, two studies have assessed vancomycin prophylaxis: both demonstrated a reduction in CR-BSI but no reduction in mortality [90, 91]. Since the prophylactic use of vancomycin is an independent risk factor for the acquisition of vancomycin-resistant enterococcus (VRE) [92], most authorities agree that the risk of acquiring VRE outweighs the benefit of using prophylactic vancomycin.

Mupirocin Ointment

Several studies have evaluated the effectiveness of mupirocin ointment applied at the insertion sites of CVCs as a means to prevent CR-BSI [93-95]. Although mupirocin reduced the risk for CR-BSI [95], mupirocin ointment has also been associated with mupirocin resistance [96, 97] and may adversely affect the integrity of polyurethane catheters [98, 99].

Nasal carriers of *S. aureus* have a higher risk for acquiring CR-BSI than do noncarriers [100, 101]. Mupirocin ointment has been used intranasally to decrease nasal carriage of *S. aureus* and lessen the risk for CR-BSI. However, resistance to mupirocin develops in both *S. aureus* and coagulase-negative staphylococci soon after routine use of mupirocin is instituted [96, 97].

Antibiotic Lock Prophylaxis

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

in order to prevent CR-BSI. Three studies have shown this to be useful in neutropenic patients with long-term catheters [102-104]. In two of the studies, patients received heparin alone (10 U/ml) or heparin plus 25 micrograms/ml of vancomycin. The third study compared vancomycin/ciprofloxacin/heparin to vancomycin/heparin to heparin alone. The rate of CR-BSI with vancomycin-susceptible organisms was significantly lower and the time to the first episode of bacteremia with vancomycin-susceptible organisms was significantly longer in patients receiving either vancomycin/ciprofloxacin/heparin or vancomycin/heparin compared to heparin alone [102-104]. One smaller study in children showed no difference between children receiving a heparin flush compared to heparin and vancomycin [105]. However, since the use of vancomycin is an independent risk factor for the acquisition of VRE [92], this practice is not routinely recommended.

An anticoagulant/antimicrobial combination consisting of minocycline and ethylenediaminetraacetic acid (EDTA) has been proposed as a lock solution because it has antibiofilm and antimicrobial activity against gram-positive, gram-negative, and *Candida* organisms [106], as well as anticoagulant properties. However, no controlled or randomized trials have demonstrated its efficacy.

Anticoagulants

Anticoagulant flush solutions are widely used to prevent catheter thrombosis. Since thrombi and fibrin deposits on catheters may serve as a nidus for microbial colonization of intravascular catheters [107, 108], the use of anticoagulants may have a role in the prevention of CR-BSI.

In a meta-analysis evaluating the benefit of heparin prophylaxis (3 U/ml in TPN, 5000 U q 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 [109]. However, there was no significant difference in the rate for CR-BSI. Since most heparin solutions contain preservatives with antimicrobial activity, it is unclear if any decrease in the rate of CR-BSI would be due to the reduced thrombus formation, the preservative, or both.

Most pulmonary artery, umbilical, and central venous catheters are available with a heparin-bonded coating. Most are heparin-bonded with benzalkonium chloride, which provides the catheters with some antimicrobial activity [110], in addition to providing an anti-thrombotic effect [111].

Warfarin has also been evaluated as a means for reducing CR-BSI by reducing thrombus formation on catheters [112, 113]. In patients with long-term CVCs, very low dose warfarin (1 mg/day) reduced the incidence of catheter thrombus. There are no data that demonstrate that warfarin reduces the incidence of CR-BSI.

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 show that the incidence of thrombophlebitis and bacterial colonization of catheters increases when catheters are left in place more than 72 hours [59, 114]. However, rates of phlebitis are not significantly different in peripheral catheters left in place 72 hours compared to 96 hours [115]. Because phlebitis and catheter colonization have been associated with an increased risk of catheter-related infection, short peripheral catheter sites commonly are rotated at 72-96 hour intervals to reduce the risk of infection, as well as the patient discomfort associated with phlebitis.

Midline Catheters

Midline catheters appear to be associated with lower rates of phlebitis than are short peripheral catheters and lower rates of infection than CVCs [116-118]. In one prospective study of 140 midline catheters, their use was associated with a BSI rate of 0.8 per 1000 catheter-days [118]. No specific risk factors, including duration of catheterization, were associated with infection. Midline catheters were in place a median of 7 days, but 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, there are no prospective, randomized studies assessing the need for routine replacement as a strategy to prevent CR-BSI associated with midline catheters.

CVCs, Including PICCs and Hemodialysis Catheters

No studies show an advantage for catheter replacement at scheduled time intervals as a method to reduce CR-BSI. Two trials assessed changing the catheter every 7 days in comparison to changing catheters as needed [119, 120]. One study involved 112 surgical ICU patients needing central venous catheters, pulmonary artery catheters, or peripheral arterial catheters [119], while the other study involved only subclavian hemodialysis catheters [120]. In both studies, there was no difference in CR-BSI in patients undergoing scheduled catheter replacement every 7 days compared to catheter replacement as needed.

Scheduled guidewire exchanges of CVCs is another strategy that has been proposed to prevent CR-BSI. The results of a meta-analysis of 12 randomized controlled trials assessing CVC management failed to prove any benefit for the reduction of CR-BSI by routine replacement of CVCs by guidewire exchange compared to catheter replacement on an as-needed basis [121]. Routine replacement of CVCs is not necessary for catheters that are functioning and have no evidence of 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 [122] and provide an important means of preserving limited venous access in some patients. Replacement of temporary catheters over a guidewire in the setting of bacteremia is not an acceptable replacement strategy, since the source of infection is usually colonization of the skin tract from the insertion site to the vein [19, 122]. However, in selected patients with tunneled hemodialysis catheters and bacteremia, catheter exchange over a guidewire in combination with antibiotic therapy may be an alternative as a salvage strategy in patients with limited venous access [123-126].

Hemodialysis Catheters

Hemodialysis catheters are the most important factor contributing to bacteremia in dialysis patients [127, 128]. The relative risk for bacteremia in patients with dialysis catheters is more than 7 times the risk for patients with primary AV fistulas [129]. Despite the National Kidney Foundation's effort to reduce the number of hemodialysis patients maintained with catheter access, the CDC annual survey indicates that catheter use increased from 12.7% in 1995 to 22.2% in 1999 [130]. Rates for bacteremia per 100 patient months were 0.2 for AV fistulas, 0.46 for grafts, 5.02 for cuffed catheters, and 8.48 for noncuffed catheters (CDC, unpublished data).

Hemodialysis catheters should be avoided in favor of AV fistulas and grafts. If temporary access is needed for dialysis, a cuffed catheter is preferable to an noncuffed catheter, even in the ICU setting if the catheter is expected to stay in place for more than 2 weeks [8].

Pulmonary Artery Catheters

Pulmonary artery catheters are inserted through a Teflon introducer and typically remain in place an average of 3 days. Most pulmonary artery catheters are heparin bonded, which

reduces not only catheter thrombosis but also microbial adherence to the catheter [131]. Meta-analysis shows standard nonheparin-bonded pulmonary artery catheter rates of CR-BSI to be 5.5 per 1000 catheter days, compared to 2.6 per 1000 catheter days for heparin-bonded pulmonary artery catheters [8]. Since most pulmonary artery catheters in use today are heparin-bonded, the relative risk of infection with these catheters is similar to that of CVC (2.6 vs. 2.3 per 1000 catheter days) [8].

A prospective study of 442 pulmonary artery catheters showed an increased risk for CR-BSI after 5 days (0/442 CR-BSI before 5 days vs. 5/442 CS-BSI after 5 days; p<0.001) [132]. A small 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 vs. 16% after 7 days; p=0.056) [133]. In patients who continue to require hemodynamic monitoring, pulmonary artery catheters do not need to be changed more frequently than 5 days. Since there are no prospective randomized trials assessing routine replacement of pulmonary artery catheters to reduce CR-BSI, no specific recommendation can be made regarding routine replacement of catheters that need to be in place for more than 5 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 CR-BSI compared to those who had a pulmonary artery catheter placed without the sleeve (p=0.002) [134].

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 CR-BSI is comparable to that of temporary central venous catheters (2.9 vs. 2.3 per 1000 catheter days) [8]. There have been no studies of scheduled catheter changes compared to changing arterial catheters on an as needed basis. One prospective observational study of 71 arterial catheters showed that 10 local infections and 4 CR-BSIs developed in patients who had peripheral arterial catheters in place for more than 4 days, compared to 1 local infection and zero CR-BSIs in patients whose catheters were in place 4 days or less (p<0.05) [133]. Since the risk of CR-BSI appears to be similar to that of short-term CVCs, it is logical to approach arterial catheters in a similar way. Since there are no prospective randomized trials assessing routine replacement of arterial catheters to reduce CR-BSI, no specific recommendation can be made regarding replacement of catheters that need to be in place for more than 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 show that replacing administration sets no more frequently than 72 hours after initiation of use is safe and cost-beneficial [135-137]. Data from a more recent study showed that rates of phlebitis were not significantly different if administration sets were left in place 96 hours compared to 72 hours [115]. It may be logical to change administration sets more frequently if a fluid that enhances microbial growth is used (i.e., lipid emulsions or blood products) [138-140].

Stopcocks, used for injection of medications, administration of IV infusions, or collection of blood samples, represent an important potential portal of entry for microorganisms into vascular access catheters and IV fluids. Stopcock contamination is common, occurring in 45% and 50% in most series. Whether such contamination is an important entry point of CR-BSI 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 [141].

Needleless Intravascular Catheter Systems

Attempts to reduce the incidence of sharp injuries and the resultant risk of transmission of bloodborne infections to healthcare workers have led to the design and introduction of needleless infusion systems. When the devices are used according to manufacturers' recommendations, they do not appear to have a major influence on the incidence of CR-BSI [142-149].

Multidose Parenteral Medication Vials

Parenteral medications commonly are dispensed in multidose parenteral medication vials that may be used for prolonged periods for one or more patients. Although the overall risk of extrinsic contamination of multidose vials appears to be small [150], the consequences of contamination may be serious.

SPECIAL CONSIDERATIONS FOR INTRAVASCULAR CATHETER-RELATED INFECTIONS IN PEDIATRIC PATIENTS

Prevention of CR-BSI in children requires a few additional considerations, although only a limited number of studies have been performed specifically in children. Pediatric data have been derived largely from studies in neonatal or pediatric intensive care units and pediatric oncology patients.

Epidemiology

As in adults, most BSIs in pediatric patients are related to 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 [11, 151]. Umbilical and central catheter-associated BSI rates for neonatal ICUs ranged from 11.6 per 1000 catheter days in children with birthweight <1000 grams to 4.0 per 1000 catheter days in children whose birthweight was >2500 grams[11]. Compared with the rate of CR-BSI in most adult ICUs [9], catheter utilization rates were comparable in adult and pediatric ICUs [151, 152].

Microbiology

As in adults, most CR-BSIs in children are caused by coagulase-negative staphylococci, which accounted for 37.7% of BSIs in pediatric ICUs reporting to NNIS during 1992-1999 [9]. Gram-negative bacteria accounted for 25% of BSIs reported in pediatric ICUs [151], whereas enterococci and *Candida* spp. accounted for 10% and 9%, respectively [151].

Peripheral Venous Catheters

As in adults, the use of peripheral venous catheters in pediatric patients may be complicated by phlebitis, infusion extravasation, and catheter infection [153]. Catheter location, infusion of parenteral nutritional fluids with continuous IV lipid emulsions, and length of ICU stay before catheter insertion have all increased a pediatric patient's risk for phlebitis. However, contrary to the risk in adults, the risk of phlebitis in children has not been shown to increase with the duration of catheterization [153, 154].

Peripheral Arterial Catheters

In a prospective study of 340 peripheral arterial catheters in children, 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 [155]. Although there was a correlation between duration of arterial catheterization and risk of catheter colonization, the risk remained constant for 2 to 20 days at 6.2% [155].

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 appear to be similar for umbilical vein catheters and umbilical artery catheters. An estimated 40-55% of umbilical artery catheters were colonized and 5% resulted in CR-BSI [156-158]. Umbilical vein catheters were reported to be associated with colonization in 22% to 59% of cases [156-158], and CR-BSI in 3% to 8% of cases [157]. Although CR-BSI rates do not appear to be different with umbilical catheters in the high position (above the diaphragm) compared to the low position (below the diaphragm and above the aortic bifurcation), there is a lower incidence of vascular complications without an increase in adverse sequelae with catheters in the high position [157].

 Risk factors for infection appear to differ between umbilical artery and vein catheters. Neonates with very low birth weight and prolonged receipt of antibiotic were at increased risk for umbilical artery CR-BSIs [157]. In contrast, those with higher birth weight and receipt of parenteral nutrition fluids were at increased risk for umbilical vein CR-BSI. Duration of catheterization was not an independent risk factor for infection of either type of umbilical catheter.

CVCs

 Because of the limited vascular sites, the required frequency of catheter replacement in children is particularly important. In a study that examined the frequency of central venous catheter replacement in PICU patients by using survival analysis techniques, the group of catheters studied (n=397) remained free of infection for a median of 23.7 days [159]. More importantly, there was no relationship between duration of catheterization and the daily probability of infection (r=0.21, p>0.1), suggesting that routine replacement of central venous catheters would not be expected to reduce the incidence of catheter-related infection [159].

PART II: RECOMMENDATIONS

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, 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).

As in previous Centers for Disease Control and Prevention (CDC)/Healthcare Infection Control Practices Advisory Committee (HICPAC) guidelines, 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 epidemiological studies.

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

No recommendation; unresolved issue. Practices for which evidence is insufficient or no consensus regarding efficacy exist.

Recommendations regarding the frequency of replacing catheters, dressings, administration sets, and fluids are summarized in Table 4.

GENERAL RECOMMENDATIONS FOR ALL INTRAVASCULAR CATHETERS IN ADULT AND PEDIATRIC PATIENTS

I.   Healthcare worker education and training
   A.   Educate healthcare workers regarding 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. Category IA [36, 41-44, 160-165].
   B.   Assess competence and compliance with guidelines periodically for all individuals who insert and manage intravascular catheters. Category IA [36, 42, 43, 160, 166].
   C.   Ensure appropriate nursing staff-to-patient ratios in ICUs. Category IB [45, 167, 168].

II.   Surveillance for catheter-related infection
   A.   Monitor the catheter sites visually or by palpation through the intact dressing on a regular basis. The frequency of examination will depend on the clinical situation for the individual patient. If the patient has tenderness at the insertion site, fever without obvious source, or other manifestations suggesting local or bloodstream infection, the dressing should be removed to allow thorough examination of the site. Category IB [1, 169-171].
   B.   Encourage patients to report any changes in their catheter site or any new discomfort to their healthcare provider. Category II.
   C.   Record the operator, date and time of catheter insertion and removal, and dressing changes in a standardized location. Category II.
   D.   Do not routinely culture catheter tips. Category IA [172-174].

III.   Hand hygiene
   A.   Observe proper hand hygiene 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, or dressing an intravascular catheter. Category IA [42, 62, 175-179].
   B.   Use of gloves does not obviate the need for hand hygiene. Category IA [42, 177, 178].

IV.   Aseptic technique during catheter insertion and care
   A.   Maintain aseptic technique for the insertion and care of intravascular catheters. Category IA [19, 63, 180, 181].
   B.   Wear clean or sterile gloves when inserting an intravascular catheter as required by the Occupational Safety and Health Administration (OSHA) Bloodborne Pathogens Standard. Category IC. Wearing clean gloves is acceptable for the insertion of peripheral intravascular catheters if aseptic technique can be maintained. Sterile gloves must be worn for the insertion of arterial and central catheters. Category IA [180, 182].
   C.   Wear clean or sterile gloves when changing the dressing on intravascular catheters. Category IC.

V.   Catheter insertion
     Do not routinely use cutdown procedures as a method to insert catheters. Category IA
     [183-185].
VI. Catheter site care
     A.   Cutaneous antisepsis
          1.   Disinfect clean skin with an appropriate antiseptic before catheter
               insertion and at the time of dressing changes. A 2% chlorhexidine-based
               preparation is preferred. Alternatively, tincture of iodine, an iodophor, or
               70% alcohol could be used. Category IA [65, 67, 186, 187]. No
               recommendation for the use of chlorhexidine in infants less than 2 months
               of age. Unresolved issue.
          2.   Allow the antiseptic to remain on the insertion site and to dry before
               inserting the catheter. Allow povidone iodine to remain on the skin for at
               least 2 minutes, or longer if it is not yet dry before inserting the catheter.
               Category IB [65, 67, 186, 187].
          3.   Do not apply organic solvents (e.g., acetone or ether) to the skin before
               insertion of catheters or during dressing changes. Category IB [188].
VII. Catheter site dressing regimens
     A.   Use either a sterile gauze or sterile transparent semipermeable dressing to cover
          the catheter site. Category IA [132, 189-191].
     B.   Well-healed tunneled CVC sites may not require dressings. Category II.
     C.   If the patient is diaphoretic, or if the site is bleeding or oozing, a gauze dressing is
          preferred. Category II [132, 189-191].
     D.   Replace catheter site dressing if the dressing becomes damp, loosened, or visibly
          soiled. Category IB [132, 189].
     E.   Change dressings regularly for adult and adolescent patients; the frequency of
          such changes must be determined individually depending on the circumstances of
          the patient, but should be done at least weekly. Category II [190].
     F.   Do not use topical antibiotic ointment or creams on insertion sites because of their
          potential to promote fungal infections and antimicrobial resistance. Category IA
          [96, 192].
     G.   Do not submerge the catheter under water. Showering may be permitted if
          precautions can be taken to reduce the likelihood of introducing organisms into
          the catheter, e.g., use an impermeable covering for the catheter and connecting
          device during the shower. Category II [193, 194].
VIII. Selection and replacement of intravascular catheters
     A.   Select the catheter, the insertion technique, and the insertion site with the lowest
          risk of complications (infectious and noninfectious) for the anticipated type and
          duration of intravenous (IV) therapy. Category IA [19, 52, 56, 195-197].
     B.   Remove any intravascular catheter that is no longer essential. Category IA [198,
          199].
     C.   Do not routinely replace central venous or arterial catheters solely for the
          purposes of reducing the incidence of infection. Category IB [121, 122, 200].
     D.   Replace peripheral venous catheters every 96 hours in adults to prevent phlebitis.
          Category IB [115]. In pediatric patients, leave peripheral venous catheters in place
          until intravenous therapy is completed, unless a complication occurs. Category IB
          [153, 154, 201, 202].

E.   Replace all catheters inserted under emergency conditions within 48 hours when adherence to aseptic technique cannot be enssured. Category II [19, 63, 180, 181].

F.   Use clinical judgement to determine when to replace a catheter that could be a source of infection. For example, do not routinely replace catheters in patients whose only indication of infection is fever. Venous catheters do not necessarily need to be replaced routinely in patients who are bacteremic or fungemic if the source of infection is unlikely to be the catheter. Category II [203].

G.   Replace all CVCs if the patient is hemodynamically unstable and CR-BSI is suspected. Category II [203].

H.   Do not use guidewire techniques to replace catheters for which there is a clinical suspicion for CR-BSI. Category IB [121, 122].

IX.   Replacement of administration sets*, needleless systems, and parenteral fluids

A.   Replace administration sets, including secondary sets and add-on devices, no more frequently than at 96-hour intervals, unless CR-BSI is suspected or documented. Category IA [115, 135-137].

B.   Replace tubing used to administer blood, blood products, or lipid emulsions within 24 hours of initiating the infusion. Category II [140, 204, 205].

C.   Needleless intravascular devices

    1.   Change the needleless components at least as often as the administration set. Category II [142-144, 146-149].

    2.   Change caps no more frequently than every 96 hours or according to manufacturers' recommendations. Category II [142, 144, 147, 148].

    3.   Minimize leaks and breaks in the system by making sure that all components of the system are compatible. Category II [145].

    4.   Minimize contamination risk by using aseptic technique when accessing needleless systems. Category IB [144, 145, 147].

D.   Parenteral fluids

    1.   Complete the infusion of lipid emulsions within 24 hours of hanging the emulsion. Category IB [138-140, 206].

    2.   Complete infusions of blood within 4 hours of hanging the blood. Category IC [207-210].

    3.   No recommendation for the hang time of other parenteral fluids. Unresolved issue.

X.   Intravenous injection ports

A.   Clean injection ports with 70% alcohol or an iodophor before accessing the system. Category II [211, 212].

B.   Cap all stopcocks when not in use. Category IB [211].

XI.   Preparation and quality control of intravenous admixtures

A.   Admix all routine parenteral fluids in the pharmacy in a laminar-flow hood using aseptic technique. Category IB [213, 214].

B.   Do not use any container of parenteral fluid with visible turbidity, leaks, cracks, particulate matter, or if the manufacturer's expiration date has passed. Category IB [213].

C.   Use single-dose vials for parenteral additives or medications whenever possible. Category II [213, 215].

D.   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. Category II [212].
3. Use a sterile device to access a multidose vial and avoid touch contamination of the device before penetrating the access diaphragm. Category IA [211, 216].
4. Discard multidose vial if sterility is compromised. Category IA [211, 216].

XII. In-line filters
Do not use filters routinely for infection control purposes. Category IA [71, 217].

XIII. Intravenous therapy personnel
Designate trained personnel for the insertion and maintenance of intravascular catheters. Category IB [43, 44, 189].

XIV. Prophylactic antimicrobials
Do not administer intranasal or systemic antimicrobial prophylaxis routinely before insertion or during use of an intravascular catheter as a method to prevent catheter colonization or bloodstream infection. Category IA [87, 88, 97, 218].

PERIPHERAL VENOUS CATHETERS, INCLUDING MIDLINE CATHETERS, IN ADULT AND PEDIATRIC PATIENTS

I. Selection of peripheral catheter
   A. Select catheters based on the intended purpose and duration of use, known complications (e.g., phlebitis and infiltration), and experience at the institution. Category IB [59, 60, 219].
   B. Avoid the use of steel needles for the administration of fluids and medication that may cause tissue necrosis if extravasation occurs. Category IA [59, 60].
   C. Use a midline catheter or PICC when the duration of IV therapy is expected to exceed 6 days. Category IB [219].

II. Selection of peripheral catheter insertion site
   A. In adults, use an upper extremity site in preference to one on a lower extremity for catheter insertion. Replace a catheter inserted in a lower extremity site to an upper extremity site as soon as it is feasible. Category IB [59, 220].
   B. In pediatric patients, the hand, the dorsum of the foot, or the scalp may be used as the catheter insertion site. Category II.
   C. Replacement of catheter
      1. Inspect the catheter insertion site daily. Category II.
      2. Remove peripheral venous catheters if the patient develops signs of phlebitis (i.e., warmth, tenderness, erythema, palpable venous cord), infection, or a malfunctioning catheter. Category IB [58].
      3. In adults, replace short, peripheral venous catheters every 96 hours to reduce the risk of phlebitis. Category IA [115, 221].
      4. Do not routinely replace midline catheters as a means to reduce the risk for infection. Category IB [118].
      5. In pediatric patients, peripheral venous catheters may be left in place until intravenous therapy is completed, unless a complication occurs. Category IB [153, 154, 201, 202].

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. Category IA [96, 192].

CENTRAL VENOUS CATHETERS, INCLUDING PICC, HEMODIALYSIS ,AND PULMONARY ARTERY CATHETERS, IN ADULT AND PEDIATRIC PATIENTS

I.   Surveillance for catheter-related infection
   A.   Conduct surveillance for CR-BSI in ICUs and other patient populations suspected of having a high rate of CR-BSI to determine catheter-specific bloodstream infection rates, to monitor trends in those rates, and to assist in identifying lapses in infection control practices. Category IA [3, 9, 13, 222-225].
   B.   Express ICU data as the number of catheter-associated BSIs per 1000 catheter-days to facilitate comparisons with national data in comparable patient populations and healthcare settings. Category IB [3, 9, 13, 222-225].
   C.   Investigate events leading to serious, unexpected, life-threatening or fatal outcomes. This includes any process variation for which a recurrence would carry a significant chance of a serious adverse outcome. Category IC [10].
II.   General Principles
   A.   Use a CVC with the minimum number of ports or lumens essential for the management of the patient. Category IB [226-229].
   B.   Use an antimicrobial or antiseptic-impregnated CVC in adults if
      1)   despite full adherence to maximal barrier precautions, there is still a high rate of CR-BSI (e.g., more than 3.3/1000 catheter days). Category IB [75-77, 81, 230].
      2)   patients are expected to be at high risk for CR-BSI (e.g. patients are receiving total parentral nutrition (TPN), are neutropenic, or are in an ICU **and** the catheter is expected to remain in place more than 4 days. Category II [75-77, 81, 230].
      3)   No Recommendation in other patients whose catheter is expected to stay in place more than 4 days. Unresolved issue.
      4)   No Recommendation for the use of impregnated catheters in children. Unresolved issue.
   C.   Designate trained personnel with documented competence and provide adequate supervision for trainees who perform catheter insertion. Category IA [36, 42, 43, 160, 165, 166].
   D.   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 central venous catheter is preferable. Category II [231, 232].
   E.   Use a cuffed central venous catheter for dialysis if the period of temporary access is anticipated to be prolonged (e.g., more than 2 weeks) Category IB [233].
   F.   Use a fistula or graft instead of a central venous catheter for permanent access for dialysis. Category IB [129].
   G.   Do not use hemodialysis catheters for blood drawing or applications other than hemodialysis except during dialysis or under emergency circumstances. 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 of mechanical complications (e.g.,

pneumothorax, subclavian artery puncture, subclavian vein laceration, subclavian vein stenosis, hemothorax, thrombosis, air embolism, catheter misplacement). Category IA [19, 52, 56, 197].

B. To minimize infection risk, use a subclavian site for nontunneled CVC placement rather than a jugular or a femoral site. Category IB [19, 52, 56].

C. 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. Category IA [234-238].

IV. Barrier precautions during catheter insertion

A. Use sterile technique including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile sheet, for the insertion of central venous catheters or guidewire exchange. Category IA [19, 63].

B. Use a sterile sleeve to protect pulmonary artery catheters during insertion. Category IB [134].

V. Replacement of catheter

A. Do not routinely replace central venous catheters or PICCs as a method to prevent catheter-related infections. Category IB [119, 121, 122].

B. Do not routinely replace hemodialysis catheters as a method to prevent catheter-related infection. Category IB [120].

C. Do not routinely replace pulmonary artery catheters more frequently than 7 days as a method to prevent catheter-related infections. Category IB [132, 133].

D. Do not remove central venous catheter or PICCs solely because of fever. Use clinical judgement regarding the appropriateness of removing the catheter if there is evidence of infection elsewhere. Category II [239].

E. Guidewire exchange

1. Do not use guidewire exchanges routinely for non-tunneled catheters. Category IB [122, 240].

2. Use a guidewire exchange to replace a malfunctioning non-tunneled catheter if there is no evidence of infection and the risk of inserting a catheter into a new site is unacceptably high (e.g., due to obesity, coagulopathy). Category IB [122, 240].

3. Use a new set of sterile gloves prior to handling the new catheter when guidewire exchanges are performed. Category II [19, 63].

VI. Catheter and catheter site care

A. General measures
Designate one port exclusively for hyperalimentation if a multilumen catheter is used to administer parenteral nutrition. Category II [241].

B. Antibiotic lock solutions
Do not routinely use antibiotic lock solutions as a means of preventing CR-BSI. Use prophylactic antibiotic lock solution only in special circumstances (e.g., in treating a patient with a long-term catheter or port who has a history of multiple CR-BSIs despite optimal aseptic technique). Category II [102, 103, 242, 243].

C. Catheter site dressing regimens

1. Replace catheter site dressing when the dressing becomes damp, loosened, or soiled, or when inspection of the site is necessary. Category IA [57, 132, 190].

2. Replace dressings used on short-term central catheter sites every 2 days for gauze dressings and every 7 days for transparent dressings, except in

       pediatric patients because in these patients the risk of dislodging the catheter outweighs the benefit of changing the dressing. Category IB [190].

    3.   Replace dressings used on tunneled or implanted central catheter sites no more than once per week, until the insertion site has healed. Category IB [190]. The frequency of catheter dressing changes over well-healed catheter exit sites is an unresolved issue.

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

E.   Do not use chlorhexidine sponge dressings in neonatesless than 7 days old or of gestational age less than 26 weeks. Category II [244].

F.   Ensure that catheter site care is compatible with the catheter material. Category IB [98, 99].

G.   Use a sterile sleeve for all pulmonary artery catheters. Category IB[134].

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. Category IB [247-251].

II.   Replacement of catheter and pressure monitoring system

    A.   Replace peripheral arterial catheters and relocate catheter insertion sites no more frequently than every 5 days for infection control purposes. Category IB [133, 200, 252].

    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. Category IB [19, 248].

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. Category IA [247, 253-255].

        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. Category II [250, 256].

        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. Category IA [250].

        4.   Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit. Category IA [250, 257, 258].

    B.   Sterilization or disinfection of pressure monitoring systems

        1.   Use disposable transducers. Category IB [250, 257-260].

2. Sterilize reusable transducers according to the manufacturers' instructions if the use of disposable transducers is not feasible. Category IA [250, 257-260].

RECOMMENDATIONS FOR UMBILICAL CATHETERS

I.   Replacement of catheters
   A.   Umbilical artery catheters should be removed and not replaced if any signs of CR-BSI, vascular insufficiency, or thrombosis occur. Category II [261].
   B.   Umbilical venous catheters should be removed and not replaced if any signs of CR-BSI or thrombosis occur. Category II [261].
   C.   No recommendation for treating through an umbilical venous catheter suspected of being infected. Unresolved issue.
   D.   Umbilical venous catheters should be replaced only if mechanical malfunction of the catheter occurs. Category II.

II. Catheter site care
   A.   Cleanse the umbilical insertion site with an appropriate antiseptic before catheter insertion. Avoid iodine-containing agents because of the potential effect on the neonatal thyroid. Category IB [67, 156, 157, 262, 263].
   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. Category IA [96, 192].
   C.   Add low doses of heparin (0.5–1.0 u/ml TPN, 5000 u q 6 hr or 12 hr) to the fluid infused through umbilical arterial catheters. Category IB [264-266].
   D.   Remove umbilical catheters as soon as possible when not needed or when there is any sign of vascular insufficiency to the lower extremities. Optimally, umbilical artery catheters should not be left in place over 5 days. Category II [261, 267].
   E.   Umbilical venous catheters should be removed as soon as possible when not needed but can be used up to 14 days if managed aseptically. Category II [268, 269].

* Administration sets 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 may be connected to the catheter and may be considered a portion of the catheter to facilitate aseptic technique when changing administration sets.

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	less than 3 inches	phlebitis with prolonged use; rarely associated with bloodstream infection
Peripheral arterial catheters	usually inserted in radial artery; can be placed in femoral, brachial, or posterior tibial arteries	less than 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	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 or longer depending on patient size	account for majority of CR-BSI
Pulmonary artery catheters	inserted through a teflon introducer in a central vein (subclavian, internal jugular, or femoral)	30 cm or longer depending on patient size	usually heparin bonded; similar rates of bloodtream infection as CVC; subclavian site preferred to reduce infection risk
Peripherally inserted central venous catheters (PICC)	inserted into basilic, cephalic or brqaachial veins and enter the superior vena cava	20 cm or longer depending on patient size	lower rate of infection than nontunneled CVCs
Tunneled central venous catheters	implanted into subclavian, internal jugular or femoral veins	8 cm or longer depending on patient size	cuff inhibits migration of organisms into catheter tract; lower rate of infection than nontunnelled CVC
Totally implantable devices	tunneled beneath skin and have subcutaneous port accessed with a needle; implanted in subclavian or internal jugular vein	8 cm or longer depending on patient size	lowest risk for CR-BSI; 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 or less, depending on patient size catheters	risk for CR-BSI similar with 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 1995-May 2000 [9].

Type of ICU	Number of ICUs	Catheter days	Pooled mean/1000 catheter-days
Burn	16	32,390	10.0
Cardiothoracic	60	332,992	2.8
Medical	126	548,124	6.1
Medical/surgical			
Major teaching	104	447,618	5.3
All others	162	698,225	4.1
Neurosurgical	46	101,409	4.9
Pediatric	70	234,100	7.7
Respiratory	6	18,373	3.6
Trauma	24	87,031	7.8

Table 3. Most common pathogens isolated from bloodstream infections. [9, 12].

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
P. aeruginosa	4	4
Enterobacter	5	5
K. pneumoniae	4	3
Candida spp	8	8

Table 4. 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 every 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 dressingsmore 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 96-hour intervals unless clinically indicated. Replace tubing used to administer blood, blood products, or lipid emulsions within 24 hours of completing 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.
Midline catheters	*No recommendation* for the frequency of the catheter replacement.	As above.	As above.	As above.
Peripheral arterial catheters	In *adults*, replace catheters and relocate insertion sites no more frequently than every 4-5 days. 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).

(continued)

Table 4. (cont.) 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
Central venous catheters including peripherally inserted central catheters and hemodialysis catheters*	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 96-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	Replace catheter no more frequently than 7 days. If feasible, replace the arterial catheter introducer no more often than every 7 days.	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 96-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.
*Includes nontunneled catheters, tunneled catheters, and totally implanted devices				

Appendix 1. 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 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 bloodstream infection
Pocket Infection	Purulent fluid in the subcutaneous pocket of a totally implanted intravascular catheter that may or may not be associated with spontaneous rupture and drainage or necrosis of the overlaying skin, in the absence of concomitant bloodstream infection
Infusate-Related Bloodstream Infection	Concordant growth of the same organism from the infusate and blood cultures (preferably percutaneously drawn) with no other identifiable source of infection
Catheter-related Bloodstream Infection	Bacteremia/fungemia in a patient with an intravascular catheter with at least one positive blood culture and with clinical manifestations of infections (i.e., fever, chills, and/or hypotension) and no apparent source for the bloodstream infection except the catheter or any of the following: 1 a positive semiquantitative (>15 CFU/catheter segment) or quantitative (>10^3 CFU/catheter segment catheter) culture whereby the same organism (species and antibiogram) is isolated from the catheter segment and peripheral blood. 2 simultaneous quantitative blood cultures with a $\geq$5:1 ratio (central venous catheter (CVC) vs. peripheral), 3 differential time period of CVC culture vs. peripheral blood culture positivity of >2 hours.

Surveillance definitions for intravascular catheter associated infections, National Nosocomial Infections Surveillance System [270].

Laboratory-confirmed bloodstream infection

Must 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 (>38°C), chills, or hypotension, and at least one of the following:

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

> Common skin contaminant (e.g., diptheroids, *Bacillus* species, *Propionibacterium* species, 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.

> Positive antigen test on blood (e.g., *Hemophilus 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 <1 year of age has at least one of the following signs or symptoms: fever (>38°C), hypothermia (<37°C), apnea, or bradycardia, and at least one of the following:

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

> Common skin contaminant (e.g., diptheroids, *Bacillus* species, *Propionibacterium* species, 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.

> Positive antigen test on blood (e.g., *Hemophilus 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
Must 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 (>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 <1 year of age has at least one of the following clinical signs or symptoms with no other recognized cause: fever (>38°C), hypothermia (<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 bloodstream infection
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.

> Bloodstream infection is considered to be associated with a central line if the line was in use during the 48-hour period before development of the bloodstream infection. If the time interval between onset of infection and device use is longer than 48 hours, there must 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. Must 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 (>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.

Appendix 2. Healthcare Infection Control Practices Advisory Committee Membership, August 2001

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