Guidelines for the Prevention of Intravascular Catheter-Related Infections

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Introduction

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 healthcare settings. This report was prepared by a working group comprising members from professional organizations representing the disciplines of critical care medicine, infectious diseases, healthcare 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 2002. These guidelines are intended to provide evidence-based recommendations for preventing catheter-related infections. Major areas of emphasis include 1) educating and training healthcare personnel 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 and chlorhexidine impregnated sponge dressings 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 emphasize performance improvement by implementing bundled strategies, documenting and reporting rates of compliance rates with all components of the bundle as benchmarks for quality assurance and performance improvement.

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.

Intravascular Catheter-Related Infections in Adult and Pediatric Patients: An Overview

Background

In the United States, 15 million central vascular catheter (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 intensive care units (ICUs) each year [1]. Catheter-related bloodstream infections (CRBSI) independently increase hospital costs and length of stay [2-5], but have not been shown to independently increase mortality. While 80,000 CVC-associated BSIs occur in ICUs each year [1], a total of 250,000 cases of CVC-associated BSIs have been estimated to occur annually, if entire hospitals are assessed [6]. By several analyses, the cost of CVC-associated BSI is substantial, both in terms of morbidity and financial resources expended. To improve patient outcome and to reduce healthcare costs, there is considerable interest by healthcare personnel, insurers, regulators, and patient advocates reducing the incidence of these infections. This effort should be multidisciplinary, involving healthcare personnel who order the insertion and removal of CVCs, those personnel who insert and maintain intravascular catheters, infection control personnel, healthcare managers from the CEO down to those who allocate resources, and patients who are capable of assisting in the care of their catheters.

Personnel should recognize that the goal of an effective prevention program is the reduction in catheter-related infections. Elimination of catheter-related infection is a laudable goal; demonstrating that elimination of CRBSIs can be sustained and encompass CVCs placed at all points of care, e.g., ICU, med-surg, home care, etc., is challenging. There are programs that have demonstrated success, but most programs will recognize some catheter-related infections over time. The goal of the measures discussed in this document is to reduce the rate to as low as feasible given the specific patient population

being served, the universal presence of microorganisms in the human environment, and the limitations of current strategies and technologies.

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. Potentially infectious episodes must be evaluated clinically and microbiologically and documented in the record; the data must be reviewed by well informed and fairly adjudicated personnel as to whether an episode is due to infection or contamination and if infection is present, whether it is related to the CVC or to a secondary source. Although CRBSI is a suitable parameter because it represents the most serious form of catheter-related infection, it is often problematic to precisely establish the diagnosis given the clinical setting of the patient (the catheter is not always removed), limited availability of microbiologic methods (many labs do not use

quantitative blood cultures or differential time to positivity), and support by direct care personnel (labeling must be accurate). Given these challenges, simpler automated methods relying on microbiological data alone, albeit less precise, may offer convenient alternatives to manual surveillance methods. Simplified objective criteria may be potentially superior to clinical criteria in identifying the true differences in CRBSI rates between institutions [7-10].

Healthcare personnel should recognize the difference between the surveillance definition (i.e., the definition that is used to benchmark institutions reporting to the National Healthcare Safety Network [NHSN] and clinical definitions. The NHSN surveillance definition is for BSIs, including central-line associated BSIs, when other documented sites of infection have been excluded (http://www.cdc.gov/nhsn/PDFs/pscManual/4PSC_CLABScurrent.pdf)[11]. 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 unrecognized 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. Within this definition is opportunity for subjective bias since some reviewers may be more prone than others to attribute the BSI to other sources based on only vague, unconvincing information. This provides opportunities for published rates of BSIs to be influenced by assessment teams with motivation to record low rates.

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. Interpreting blood cultures drawn from catheters presents its own set of challenges, but clinical definitions have been developed to take the results of such blood cultures into account when establishing a diagnosis of CRBSI [12].Such a clinical /microbiological definition would focus on catheter-*related* BSIs. Therefore, to accurately compare a healthcare facility's CRBSI infection rate to published data, comparable definitions also should be used.

CDC and The Joint Commission recommend that the rate of catheter-associated BSIs (CABSIs) be expressed as the number of CABSIs per 1,000 CVC days [13, 14]. This parameter provides longitudinal data not expressed when the rate is expressed as the number of catheter-associated infections per 100 catheters (or percentage 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 in Adult and Pediatric Patients

National estimates of CABSI rates are available through CDC's NHSN (www.cdc.gov/nhsn). The most recently published NHSN data represent reports from 621 hospitals in 45 States and the District of Columbia that monitor infections in one or more ICUs and/or non-ICUs (e.g., patient care areas, wards) [15]. Because BSI rates are influenced by patient-related factors, such as severity of illness and type of illness (e.g., third-degree burns versus post-cardiac surgery), by catheter-related factors, (such as the condition under which the catheter was placed and catheter type), and by institutional factors (e.g., bed-size, academic affiliation), these aggregate, risk-adjusted rates can be

used as benchmarks against which hospitals can make intra- and inter-facility comparisons.

Among hospitals participating in NHSN during 2006, the reported pooled mean rates of central venous CABSIs ranged from 1.3/1000 catheter days on inpatient medical/surgical wards to 5.6/1000 catheter days in burn ICUs (Table 2). In neonatal nurseries for infants weighing less than 1,000 grams (Level III), central line-associated BSI rates ranged from 3.3-3.7/1,000 catheter days [15]. In these nurseries, umbilical catheter rates also varied by birth weight category, ranging from 0.9/1,000 catheter days among neonates weighing above 1,500 grams to 4.7/1,000 catheter days among neonates weighing 750 grams or less [15]. Secular trends suggest a reduction in the incidence of central venous CABSIs occurring in ICUs over the past 20 years.

The most commonly reported causative pathogens for hospital acquired BSIs remain coagulase-negative staphylococci, *Staphylococcus aureus*, enterococci, and *Candida* spp. [16]. Gram negative bacilli accounted for 19% and 21% of catheter associated BSIs reported to CDC [17] and the Surveillance and Control of Pathogens of Epidemiological Importance (SCOPE) database, respectively [16].

For all common pathogens causing CRBSIs, antimicrobial resistance is a problem, particularly in ICUs. Although methicillin-resistant *Staphylococcus aureus* (MRSA) now accounts for more than 50% of all *Staphylococcus aureus* isolates obtained in ICUs, the incidence of MRSA CABSIs has decreased in recent years, perhaps as a result of prevention efforts [18] For gram negative rods, antimicrobial resistance to third generation cephalosporins among *Klebsiella pneumoniae* and *E. coli* have increased

significantly as did imipenem and ceftazidine resistance among *Pseudomonas aeruginosa* [17]. *Candida* spp. are increasingly noted to be fluconazole resistant.

As in adults, the majority of BSIs in children are associated with the use of an intravascular catheter. From 2002 through 2004, the pooled mean CABSI rate for all pediatric ICUs reporting data to NNIS was 6.6 per 1,000 catheter days [14]. This rate has decreased compared to the 1995-2000 data, but is consistently higher than that reported in adult medical-surgical ICUs. Umbilical catheter and CVC-associated BSI rates for neonatal ICUs ranged from 3.7-4.7 per 1,000 catheter days in children with birth weight <750 gram to 1.0-2.0 per 1,000 catheter days in children whose birth weight was >2,500 gram [19]. Catheter utilization rates were comparable in adult and pediatric ICUs [20, 21].

The distribution of types of organisms causing infection is similar in pediatric ICUs and adult ICUs [21]. 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 [21]**.** Among neonates with percutaneously placed central venous catheters, coagulase-negative staphylococci are responsible for 75% of CRBSIs [22, 23].

Pathogenesis

There are four recognized routes for contamination of catheters: 1) migration of skin organisms at the insertion site into the cutaneous catheter tract and along the surface of the catheter with colonization of the catheter tip; this is the most common route of infection for short-term catheters [24-26]; 2) direct contamination of the catheter or catheter hub by contact with hands or contaminated fluids or devices [27, 28]; 3) less

commonly, catheters might become hematogenously seeded from another focus of infection [29]; and 4) rarely, infusate contamination might lead to CRBSI [30].

Important pathogenic determinants of catheter-related infection are 1) the material of which the device is made; 2) the host factors consisting of protein adhesions, such as fibrin and fibronectin that form a sheath around the catheter [31]; and 3) the intrinsic virulence factors of the infecting organism, including the extracellular polymeric substance (EPS) produced by the adherent organisms [32]. Some catheter materials also have surface irregularities that enhance the microbial adherence of certain species (e.g., *S. epidermidis* and *C. albicans*) [33, 34]. Catheters made of these materials are especially vulnerable to microbial colonization and subsequent infection. After the formation of the fibrin sheath, silastic catheters are more prone to catheter infections than polyurethane catheters [31]. On the other hand, biofilm formation by *C. albicans* occurs more intensely on silicone elastomer catheter surfaces than polyurethane catheters [33]. Modification of the biomaterial surface properties has been shown to influence the ability of *C. albicans* to form biofilm [34]. Additionally, certain catheter materials are more thrombogenic than others, a characteristic that also might predispose to catheter colonization and catheter-related infection [35, 36]. This association has led to emphasis on preventing catheter-related thrombus as an additional mechanism for reducing CRBSI [37, 38].

The adherence properties of a given microorganism in relationship to host factors are also important in the pathogenesis of catheter-related infection. For example, *S. aureus* can adhere to host proteins (e.g., fibrinogen, fibronectin) commonly present on catheters by expressing clumping factors (ClfA and ClfB) that bind to the protein

adhesins [31, 36, 39, 40]. Furthermore, adherence is enhanced through the production of EPS by microbial organisms, such as coagulase-negative staphylococci [41, 42], *S. aureus* [43], *Pseudomonas aeruginosa* [44], and *Candida* spp. [45], consisting mostly of an exopolysaccharide that forms a microbial biofilm layer [32, 46]. This biofilm matrix is enriched by divalent metallic cations, such as calcium, magnesium and iron, which make it a solid enclave for microbial organisms to embed themselves [47-49]. In the presence of catheters, this biofilm potentiates the pathogenicity of various microbes 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) [42, 50, 51]. Some *Candida* spp., in the presence of glucose-containing fluids, 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 [52].

Strategies for Prevention of Catheter-Related Infections in Adult and Pediatric Patients

Education, training and staffing

Recommendations

1. Educate healthcare personnel 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 [53-61]. Category IA

2. Periodically assess knowledge of and adherence to guidelines for all persons who are involved in the insertion and maintenance of intravascular catheters [53-61]. Category IA

3. Designate only trained personnel who demonstrate competence for the insertion and maintenance of peripheral and central intravascular catheters. [60-74]. Category IA

4. Ensure appropriate nursing staff levels in ICUs to minimize the incidence of catheter-related BSIs. Observational studies suggest a ratio of 2:1 in ICUs where nurses are managing patients with CVCs [75-77]. Category IB

Background

Well-organized programs that enable healthcare personnel to become educated and to provide, monitor, and evaluate care are critical to the success of this effort. Reports spanning the past four decades have consistently demonstrated that risk for infection declines following standardization of aseptic care [53, 58, 60, 61, 78-80] and that insertion and maintenance of intravascular catheters by inexperienced staff might increase the risk for catheter colonization and CRBSI [61, 81]. Specialized "IV teams" have shown unequivocal effectiveness in reducing the incidence of catheter-related infections, associated complications, and costs [62-72]. Additionally, infection risk increases with nursing staff reductions below a critical level [76].

Site selection

Recommendations for peripheral catheters and midline catheters

1. In adults, use an upper-extremity site for catheter insertion. Replace a catheter inserted in a lower extremity site to an upper extremity site as soon as possible [82, 83]. Category IB

2. In pediatric patients, the upper or lower extremities or the scalp can be used as the catheter insertion site [82, 83]. Category II

3. Select catheters on the basis of the intended purpose and duration of use, known infectious and non-infectious complications (e.g., phlebitis and infiltration), and experience of individual catheter operators [83-85]. Category IB

4. Avoid the use of steel needles for the administration of fluids and medication that might cause tissue necrosis, if extravasation occurs [83-85]. Category IA

5. Use a midline catheter or peripherally inserted central catheter (PICC), instead of a short peripheral catheter, when the duration of IV therapy will likely exceed six days [83-85]. Category IB

Recommendations for central venous catheters

6. Weigh the risk and benefits of placing a central venous 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) [25, 86-101]. Category IA

7. Use a subclavian site, rather than a jugular or a femoral site, in adult patients to minimize infection risk for nontunneled CVC placement [25, 99, 100]. Category IA

8. No recommendation can be made for a preferred site of insertion to minimize infection risk for a tunneled CVC. Unresolved issue

9. Place catheters used for hemodialysis and pheresis in a jugular or femoral vein, rather than a subclavian vein, to avoid venous stenosis [101-105]. Category IA

10. Use ultrasound guidance to place central venous catheters to reduce the number of cannulation attempts and mechanical complications if this technology is available [106, 107]. Category 1B

11. Promptly remove any intravascular catheter that is no longer essential [108, 109]. Category IA

Background

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 [110-112]. In addition, hand veins have a lower risk for phlebitis than do veins on the wrist or upper arm [113]. As in adults, the use of peripheral venous catheters in pediatric patients might be complicated by phlebitis, infusion extravasation, and catheter infection [114]. 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 [114, 115].

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 single trial has satisfactorily compared infection rates for catheters placed in jugular, subclavian, and femoral vein. In

retrospective observational studies, catheters inserted into an internal jugular vein have usually been associated with higher risk for colonization and/or CRBSI than those inserted into a subclavian or femoral vein [25, 86-95]. Similar findings were noted in neonates in a single retrospective study [116].

Femoral catheters have been demonstrated to have high colonization rates compared to subclavian and internal jugular sites when used in adults and, in some studies, higher rates of CRBSIs [88, 93-95, 98, 99, 117]. Femoral catheters should also be avoided, when possible, because they are associated with a higher risk for deep venous thrombosis than are internal jugular or subclavian catheters [96-98, 101, 118]. One study [86] found that the risk of infection associated with catheters placed in the femoral vein is accentuated in obese patients. In contrast to adults, 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 [119-122]. 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 two meta-analyses, the use of dynamic two-dimensional ultrasound for the placement of CVCs substantially decreased mechanical complications and reduced the number of attempts at required cannulation and failed attempts at cannulation compared with the standard landmark placement [106, 107]. Evidence favors the use of two dimensional ultrasound guidance over Doppler ultrasound guidance [106]. Site selection should be guided by patient comfort, ability to secure the catheter, 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, the experience of the person inserting the catheter, and the risk for infection.

Catheters should be inserted as great a distance as possible from open wounds. In one study, catheters inserted close to open burn wounds were 1.79 times more likely to be colonized and 5.12 times more likely to be associated with bacteremia than catheters inserted farther from the wounds [123].

Type of Catheter Material

Polytetrafluoroethylene or polyurethane catheters have been associated with fewer infectious complications than catheters made of polyvinyl chloride or polyethylene [124-126]. Steel needles used as an alternative to catheters for peripheral venous access have the same rate of infectious complications as do polytetrafluoroethylene catheters [83, 84]. 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 [84].

Hand Hygiene and Aseptic Technique

Recommendations

1. Perform hand hygiene procedures, either by washing hands with conventional antiseptic containing soap and water or with waterless alcohol-based hand rubs (ABHR). Hand hygiene should be performed 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 [58, 127-131]. Category IA

2. Maintain aseptic technique for the insertion and care of intravascular catheters [25, 132-134]. Category IA

3. Wear clean gloves, rather than sterile gloves, for the insertion of peripheral intravascular catheters, if the access site is not touched after the application of skin antiseptics. Category IC

4. Sterile gloves should be worn for the insertion of arterial, central, and midline catheters [25, 132-134]; and these gloves should be changed, if a catheter is being exchanged over a guidewire (thereby contaminating the gloves) and a new sterile catheter is then handled. Category IA

4. Wear either clean or sterile gloves when changing the dressing on intravascular catheters. Category IC

Background

Hand hygiene before catheter insertion or maintenance, combined with proper aseptic technique during catheter manipulation, provides protection against infection [58]. Proper hand hygiene can be achieved through the use of either a waterless, alcohol-based product [135] or an antibacterial soap and water with adequate rinsing [127]. Appropriate aseptic technique does not necessarily require sterile gloves for insertion of peripheral catheters; a new pair of disposable nonsterile gloves can be used in conjunction with a "no-touch" technique for the insertion of peripheral venous catheters. Sterile gloves must be worn for placement of central catheters since a “no-touch” technique is not possible.

Maximal Sterile Barrier Precautions

Recommendations

1. Use maximal sterile barrier precautions, including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile full body drape, for the insertion of CVCs, PICCs, or guidewire exchange [60, 132, 136, 137]. Category IB

2. Use a sterile sleeve to protect pulmonary artery catheters during insertion [138]. Category IB

Background

Maximum sterile barrier (MSB) precautions is defined as wearing a sterile gown, sterile gloves, and cap and using a full body drape (similar to the drapes used in the operating room) during the placement of CVC. Maximal sterile barrier precautions during insertion of CVC were compared with sterile gloves and a small drape in a randomized controlled trial. The MSB group had fewer episodes of both catheter colonization (RR = 0.32, 95% CI, 0.10-0.96, P = .04) and CR-BSI (RR = 0.16, 95% CI, 0.02-1.30, P = .06). In addition, the group with MSB had infections that occurred much later and contained gram negative, rather than gram positive, organisms [132]. A study designed to examine pulmonary artery catheters also secondarily demonstrated that use of MSB precautions was one of the items that lowered risk of infection [25]. Another study evaluated an educational program directed at improving infection control practices, especially MSB. In this study, MSB use increased and CRBSI decreased [60]. A small trial demonstrated an reduced risk of skin colonization at the insertion site with maximal barrier precautions [OR 3.40, 95%CI 1.32 to 3.67] [136].

Skin Preparation

Recommendations

1. Prepare clean skin with 70% alcohol before peripheral venous catheter insertion [139]. Category IA

2. Prepare clean skin site with a 2% chlorhexidine-based preparation before central venous catheter insertion and during dressing changes. If there is a contraindication to chlorhexidine, tincture of iodine, an iodophor, or 70% alcohol can be used as alternatives [140, 141]. Category IA

3. No recommendation can be made for the safety or efficacy of chlorhexidine in infants aged <2 months. Unresolved issue

4. Allow povidone iodine to remain on the skin for at least 2 minutes or longer for the antibacterial properties to take effect, if it is not yet dry before catheter insertion. The antibacterial properties of chlorhexidine work on contact, and chlorhexidine does not require a minimum 2- minute drying time before proceeding. Catheter insertion may begin as soon as the chlorhexidine is dry[140, 141]. Category IB

Background

Two well-designed studies evaluating the chlorhexidine-containing cutaneous antiseptic regimen in comparison with either povidone iodine or alcohol for the care of an intravascular catheter insertion site have shown lower rates of catheter colonization or CRBSI associated with the chlorhexidine preparation [140, 141]. When 0.5% tincture of chlorhexidine was compared with 10% povidone iodine, no differences were seen in CVC colonization or in CRSBI [142]. In a three-armed study (2% aqueous chlorhexidine gluconate vs 10% povidone-iodine vs 70% alcohol), 2% aqueous chlorhexidine gluconate

tended to decrease CRBSI compared with 10% povidone iodine or 70% alcohol [140]. A meta-analysis of 4,143 catheters suggested that chlorhexidine preparation, rather than povidone iodine, reduced the risk of catheter-related infection by 49% (95% CI 0.28 to 0.88) [143]. An economic decision analysis based on available evidence suggested that the use of chlorhexidine, rather than povidone iodine, for CVC care would result in a 1.6% decrease in the incidence of CRBSI, a 0.23% decrease in the incidence of death, and a savings of $113 per catheter used [144]. While 2% chlorhexidine has become a standard antiseptic for skin preparation for the insertion of both central and peripheral venous catheters, 5% povidone iodine solution in 70% ethanol was associated with a substantial reduction of CVC-related colonization and infection compared with 10% aqueous povidone iodine [145].

Catheter site dressing regimens

Recommendations

1. Use either sterile gauze or sterile, transparent, semi-permeable dressing to cover the catheter site [146-149]. Category IA

2. If the patient is diaphoretic or if the site is bleeding or oozing, use gauze dressing until this is resolved [146-149]. Category II

3. Replace catheter site dressing if the dressing becomes damp, loosened, or visibly soiled [146, 147]. Category IB

4. Do not use topical antibiotic ointment or creams on insertion sites, except for dialysis catheters, because of their potential to promote fungal infections and antimicrobial resistance [150, 151]. Category IB

5. Do not submerge the catheter or catheter site in 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) [152, 153]. Category II

6. 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 dislodging the catheter may outweigh the benefit of changing the dressing [149]. Category IB

7. Replace dressings used on tunneled or implanted CVC sites no more than once per week, until the insertion site has healed [149]Category IB

8. 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

9. Ensure that catheter site care is compatible with the catheter material [154, 155]. Category IB

10. Use a sterile sleeve for all pulmonary artery catheters [138]. Category IB

11. Use a chlorhexidine-impregnated sponge dressing for temporary short-term catheters in patients older than 2 months of age, if the CRBSI rate is higher than the institutional goal, despite adherence to basic CRBSI prevention measures, including education and training, use of chlorhexidine for skin antisepsis, and MSB [22, 156-158]. Category 1B

Background

Transparent, semi-permeable polyurethane dressings permit continuous visual inspection of the catheter site and require less frequent changes than do standard gauze and tape dressings. In the largest controlled trial of dressing regimens on peripheral

catheters, the infectious morbidity associated with the use of transparent dressings on approximately 2,000 peripheral catheters was examined [126]. 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 [126].

A meta-analysis has assessed studies that compared the risk for CRBSIs for groups using transparent dressings versus groups using gauze dressing [159]. 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 is preferred. Another systemic review of randomized controlled trials comparing gauze and tape to transparent dressings found no significant differences in CRBSIs, catheter tip colonization, or skin colonization between dressing types [160].

Chlorhexidine impregnated dressings have been used to reduce the risk of CRBSI. In the largest multicenter randomized controlled trial published to date comparing chlorhexidine impregnated sponge dressings vs standard dressings in ICU patients, rates of CRIs were reduced even when background rates of infection were low. In this study, 1636 patients (3778 catheters, 28 931 catheter-days) were evaluated. The chlorhexidine-impregnated dressings decreased the rates of major CRIs (10/1953 [0.5%], 0.6 per 1000 catheter-days vs 19/1825 [1.1%], 1.4 per 1000 catheter-days; hazard ratio [HR], 0.39 [95% confidence interval {CI}, 0.17-0.93]; $P = .03$) and CRBSIs (6/1953 catheters, 0.40

per 1000 catheter-days vs 17/1825 catheters, 1.3 per 1000 catheter-days; HR, 0.24 [95% CI, 0.09-0.65]) [156]. A randomized controlled study of 140 children used polyurethane or a chlorhexidine impregnated dressing showed no statistical difference in BSIs; however, the chlorhexidine group had lower rates of CVC colonization [158]. In 601 cancer patients receiving chemotherapy, the incidence of CRBSI was reduced in patients receiving the chlorhexidine sponge dressing compared to standard dressings (p=0.016, relative risk 0.54; confidence interval 0.31-0.94) [161]. A meta-analysis that included eight randomized controlled trials demonstrated that chlorhexidine impregnated sponges are associated with a reduction of vascular and epidural catheter exit site colonization (14.8% versus 26.9%, OR 0.47, 95% CI: 0.34 to 0.65) (overall 14.3% versus 27.2%, OR 0.40, 95% CI: 0.26–0.61; P < 0.0001), but no significant reduction in CRBSI (2.2% versus 3.8%, OR 0.58, 95% CI: 0.29–1.14, P = 0.11) [157].

Although data regarding the use of a chlorhexidine impregnated sponge in children are limited, one randomized, controlled study involving 705 neonates reported a substantial decrease in colonized catheters in infants in the chlorhexidine sponge 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. Chlorhexidine impregnated sponges were associated with localized contact dermatitis in infants of very low birth weight. In 98 neonates with very low birth weight, 15 (15%) developed localized contact dermatitis; four (1.5%) of 237 neonates weighing >1,000 g developed this reaction (p < 0.0001). 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 [22].

Patient Cleansing

Recommendation

Use a 2% chlorhexidine wash daily to reduce CRBSI [162]. Category II

Background

Daily cleansing of ICU patients with a 2% chlorhexidine impregnated washcloth may be a simple, effective strategy to decrease the rate of primary BSIs. In a single center study of 836 ICU patients, patients receiving the chlorhexidine intervention were significantly less likely to acquire a primary BSI (4.1 vs 10.4 infections per 1000 patient days; incidence difference, 6.3 [95% confidence interval, 1.2-11.0) than those bathed with soap and water [162].

Catheter Securement Devices

Recommendation

Use a sutureless securement device to reduce the risk of infection for PICCs [163]. Category II

Background

Catheter stabilization is recognized as an intervention to decrease the risk for phlebitis, catheter migration and dislodgement, and may be advantageous in preventing CRBSIs. Pathogenesis of CRBSI occurs via migration of skin flora through the percutaneous entry site. Sutureless securement devices avoid disruption around the catheter entry site and may decrease the degree of bacterial colonization. [163]. Using a sutureless secrument device also mitigates the risk of sharps injury to the healthcare personnel from inadvertent needlestick injury.

Antimicrobial/Antiseptic Impregnated Catheters and Cuffs

Recommendation

Use a chlorhexidine/silver sulfadiazine or minocycline/rifampin -impregnated CVC in adults whose catheter is expected to remain in place >5 days if, after successful implementation of a comprehensive strategy to reduce rates of CRBSI, the CRBSI rate remains above the goal set by the individual institution based on benchmark rates (Tables 2 and 3) and local factors. The comprehensive strategy should include at least 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. Category IA

Background

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 [164]. Nearly all of the studies involving antimicrobial/antiseptic-impregnated catheters have been conducted using triple-lumen, uncuffed catheters in adult patients whose catheters remained in place <30 days. Most of the studies have been conducted in adults; however, these catheters have been approved by FDA for use in patients weighing >3 kg. Two non-randomized studies [165, 166] in pediatric ICU patients suggest that these catheters may reduce risk of catheter-associated infection. No antiseptic or antimicrobial impregnated catheters currently are available for use in infants 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 of first-generation catheters [1, 167] demonstrated that such catheters reduced the risk for CRBSI compared with standard non-coated catheters. The duration of catheter placement in one study ranged from 5.1 to 11.2 days [168]. A second-generation catheter is now available with chlorhexidine coating the internal surface extending into the extension set and hubs while the external luminal surface is coated with chlorhexidine and silver sulfadiazine. 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. All three prospective, randomized studies of second-generation catheters demonstrated a significant reduction in catheter colonization, but they were underpowered to show a difference in CRBSI [169-171]. Prolonged anti-infective activity provides improved efficacy in preventing infections [172]. Although rare, anaphylaxis with the use of these chlorhexidine/silver sulfadiazine catheters has been observed [173-176].

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 [177] 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 1,000 catheter days [168].

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 [178]. The beneficial effect began after day 6 of catheterization. Silicone minocycline/rifampin impregnated CVCs with an average dwell time of over 60 days have been shown to be effective in reducing CRBSI [179]. No minocycline/rifampin-resistant organisms were reported. Two trials demonstrated that use of these catheters significantly reduced CRBSI compared to uncoated catheters [164, 179]. No comparative studies have been published using the second-generation chlorhexidine/ silver sulfadiazine catheter. Although there have been concerns related to the potential for development of resistance, several prospective clinical studies have shown that the risk is low [180, 181]. Further, no resistance to minocyline or rifampin related to the use of the catheter has been documented in the clinical setting. Two studies using decision model analysis revealed these catheters were associated with superior cost savings compared with first generation chlorhexidine/silver sulfadiazine catheters [182, 183]. Such analysis needs to be done compared to the second-generation catheters. However, as baseline rates of infection decrease and the cost of catheters decreases, the cost-benefit ratio will likely change.

The decision to use chlorhexidine/silver sulfadiazine or minocycline/rifampin impregnated catheters should be based on the need to enhance prevention of CRBSI after bundled 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

A combination platinum/silver impregnated catheter (i.e., a silver iontophoretic catheter) is available for use in the United States. Several prospective, randomized studies have been published comparing these catheters to uncoated catheters [184-187]. One study showed a reduction in the incidence density of catheter colonization and CRBSI [186], but the other studies found no difference in catheter colonization or CRBSI between the impregnated catheter and a non-impregnated catheter [87, 184, 185].

Systemic Antibiotic Prophylaxis

Recommendation

Do not administer systemic antimicrobial prophylaxis routinely before insertion or during use of an intravascular catheter to prevent catheter colonization or CRBSI [188]**.**

Category IA

Background

Several studies have examined the role of systemic antibiotic prophylaxis in prevention of catheter-related infection. A recent meta-analysis reviewed these studies in oncology patients [188]. Four studies utilized a prophylactic glycopeptide prior to catheter insertion. However, heterogeneity in these studies precludes any conclusion from being reached about efficacy

In a study examining the effect of ongoing oral prophylaxis with rifampin and novobiocin on catheter-related infection in cancer patients treated with interleukin-2 [189], a reduction in CRBSI was observed, even though 9 of 26 subjects (35%)

discontinued the prophylactic antibiotics due to side effects or toxicity. In non-oncology patients, no benefit was associated with vancomycin administration prior to catheter insertion in 55 patients undergoing catheterization for parenteral nutrition [190]. Similarly, extending perioperative prophylactic antibiotics in cardiovascular surgery patients did not reduce central venous catheter colonization [191]. A recent Cochrane review of prophylactic antibiotics in neonates with umbilical venous catheters concluded that there is insufficient evidence from randomized trials to support or refute the use of prophylactic antibiotics [192].

Late onset neonatal sepsis is often due to coagulase negative staphylococci and is thought to frequently stem from infected central venous catheters. Five trials involved a total of 371 neonates treated with vancomycin, either by continuous infusion via parenteral nutrition or intermittent dosing or placebo. The infants treated with vancomycin experienced less nosocomial sepsis (RR 0.11; 95% CI 0.05-0.24) and less sepsis due to coagulase-negative staphylococci (RR 0.33; 95% CI 0.19-0.59) [193]. However, mortality and length of stay were not significantly different between the two groups. There were insufficient data to evaluate the risk of development of vancomycin-resistant organisms.

Antibiotic/Antiseptic Ointments

Recommendation

Use povidone iodine antiseptic ointment or bacitracin/neomycin/polymyxin B 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 [139, 194-198]. Category IB

Background

A variety of topical antibiotic or antiseptic ointments have been utilized in attempts to lower the antimicrobial burden at the catheter insertion site and thus prevent infection. A number of older studies, examining primarily peripheral venous catheters, yielded varying conclusions [139, 199, 200]. In addition, the use of antibiotic ointments that have limited antifungal activity may serve to increase colonization and/or infection due to *Candida* spp [151].

More recent studies have examined this approach in high-risk patients, particularly those undergoing hemodialysis [194-197]. Three randomized, controlled trials have evaluated the use of 10% povidone iodine [195-197]. A significant decrease in colonization, exit-site infection, or bloodstream infection was observed. The beneficial effect was most prominent in subjects with nasal colonization by *S. aureus* [195-197].

Nasal carriers of *S. aureus* are more likely to experience a CRBSI than non-colonized persons [201-203]. This has prompted investigators to assess the utility of topical mupirocin, a potent anti-staphylococcal agent. Several studies have demonstrated a reduced risk of CRBSI when mupirocin ointment was applied at the catheter insertion site [195, 204-206]. Others have shown similar benefits when mupirocin was applied

nasally [202, 203, 207]. However, enthusiasm for this measure has been dampened by the rapid emergence of mupirocin resistance observed at some centers [150, 208, 209], and the potential degrading effect that mupirocin has on polyurethane catheters [154, 155].

In the only study demonstrating a significant effect on mortality, the application of bacitracin/neomycin/polymyxin B ointment at the catheter insertion site was compared to placebo in 169 hemodialysis patients [210]. Infections were observed in more patients in the placebo group than in the bacitracin/neomycin/polymyxin B group (34 versus 12%; relative risk, 0.35; 95% CI, 0.18 to 0.68; P = 0.0013). The number of infections per 1,000 catheter days (4.10 versus 1.02; P < 0.0001) and the number of bacteremias per 1,000 catheter days (2.48 versus 0.63; P = 0.0004) were also greater in the placebo group. Within the 6-month study period, there were 13 deaths in the placebo group as compared with three deaths in the bacitracin/neomycin/polymyxin B group (P = 0.004). Thus, there is evidence from one study in hemodialysis patients that bacitracin/neomycin/polymyxin B ointment can improve outcome, but no similar data exist for other patient populations [210].

Antibiotic Lock Prophylaxis, Antimicrobial Catheter Flush and Catheter Lock Prophylaxis

Recommendation

Use prophylactic antimicrobial lock solution in patients with long term catheters who have a history of multiple CRBSI despite optimal maximal adherence to aseptic technique [23, 211-228]. Category II

Background

To prevent CRBSI, a wide variety of antibiotic and antiseptic solutions have been utilized to flush or lock catheter lumens [23, 211-228]. Catheter lock is a technique by which an antimicrobial solution is used to fill a catheter lumen and then allowed to dwell for a period of time while the catheter is idle. Antibiotics of various concentrations that have been used either alone (when directed at a specific organism) or in combination (to achieve broad empiric coverage) to prophylactically flush or lock central venous catheters include vancomycin, gentamicin, ciprofloxacin, minocycline, amikacin, cefazolin, cefotaxime, and ceftazidime; while antiseptics have included alcohol, taurolidine, trisodium citrate. (Taurolidine and trisodium citrate are not approved for this use in the US). These agents are usually combined with a compound acting as an anticoagulant, such as heparin or ethylenediaminetetraacetic acid (EDTA). Most of these studies have been conducted in relatively small numbers of high-risk patients, such as hemodialysis patients, neonates, or neutropenic oncology patients. Although most studies indicate a beneficial effect of the antimicrobial flush or lock solution in terms of prevention of catheter-related infection, this must be balanced by the potential for side effects, toxicity, allergic reactions, or emergence of resistance associated with the antimicrobial agent. The wide variety of compounds used, the heterogeneity of the patient populations studied, and limitations in the size or design of studies preclude a general recommendation for use. In addition, there are no FDA-approved formulations approved for marketing, and most formulations have been prepared in hospital pharmacies. A brief overview of some of the studies follows.

At least 10 studies regarding catheter flush or lock solutions have been performed in hemodialysis patients [218, 219, 221-228]. Three meta-analyses have all demonstrated that catheter lock solutions reduce risk of CRBSI in hemodialysis patients [229-231]. In the largest of these studies, 291 subjects were enrolled in a prospective randomized comparison of 30% trisodium citrate versus heparin [223]. The rate of CRBSI was significantly lower in the group whose catheters were locked with trisodium citrate (4.1 BSI/1,000 CVC days vs. 1.1 BSI/1,000 CVC days, $P< 0.001$), and no significant difference in thrombosis or occlusion of the catheter was noted. However, if infused rapidly, concentrated citrate can result in serious hypocalcaemia, cardiac dysrhythmia, and death. The second largest study in hemodialysis subjects examined the effect of a catheter lock solution containing cefazolin, gentamicin, and heparin compared to control patients receiving only heparin [225]. In 120 subjects, the rate of CRBSI was significantly lower in those receiving the antibiotic lock solution (0.44 BSI/1,000 CVC days vs. 3.12 BSI/1,000 CVC days, $P=0.03$) [225]. Other trials in hemodialysis patients have studied minocycline, gentamicin, EDTA, heparin, taurolidine, vancomycin, and cefotaxime.

At least five studies have been conducted in pediatric oncology patients [211, 212, 215-217]. In the largest trial, 126 subjects were enrolled in a prospective, randomized, double blind study comparing vancomycin/ciprofloxacin/heparin (VCH) to vancomycin/heparin (VH) to heparin (H) alone [215]. The time to CVC-related infection was significantly longer in the VCH or VH arms of the study compared to heparin, and the rate of possible or definite catheter-related infection was significantly lower with

either of the antibiotic containing solutions compared to heparin alone (1.72/1,000 CVC days [H] vs. 0.55/1,000 CVC days [VCH] vs. 0.37/1,000 CVC days [VH]).

In a meta-analysis of seven randomized, controlled trials examining the utility of vancomycin-containing lock or flush solutions compared to heparin alone, the risk ratio for vancomycin/heparin solutions was 0.49 (95% CI 0.26-0.95, p = 0.03) [232]. Use of the catheter lock technique appeared to have greater benefit than simply flushing vancomycin through the catheter.

Recently, a prospective, double blind, randomized trial compared the utility of 70% ethanol lock versus heparinized saline for the prevention of CABSI in oncology patients. Patients receiving the ethanol lock preventive therapy were significantly less likely to experience a CABSI (0.60/1,000 CVC days vs. 3.11/1,000 CVC days; OR 0.18, 95% CI 0.05-0.65, p= 0.008) [233].

Anticoagulants

Recommendation

Do not routinely use anticoagulant therapy to reduce the risk of catheter-related infection in general patient populations [234]. Category II

Background

Shortly after insertion, intravascular catheters are coated with a conditioning film, consisting of fibrin, plasma proteins, and cellular elements, such as platelets and red blood cells [27, 235]. Microbes interact with the conditioning film to result in colonization of the catheter [236]. There is a close association between thrombosis of central venous catheters and infection [35, 237, 238]. Therefore, anticoagulants have been used to prevent catheter thrombosis and presumably reduce the risk of infection.

In a meta-analysis evaluating the benefit of heparin prophylaxis (3 units/mL in parenteral nutrition, 5,000 units every 6 or 12 hours flush or 2,500 units 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 [234]. However, no substantial difference in the rate of CRBSI was observed. In a more recent prospective, randomized trial, 204 patients with non-tunneled catheters were assigned to receive a continuous infusion of heparin (100 units/kg/d) or saline (50 mL/d) [239]. The rate of CRBSI was significantly decreased in the group receiving heparin (2.5 BSI/1,000 CVC days vs. 6.4 BSI/1,000 CVC days). 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 as heparin-bonded devices. The majority of catheters are heparin bonded with benzalkonium, which provides the catheters with antimicrobial activity [240] and provides an anti-thrombotic effect [241]. However, some catheters have heparin bound directly to the catheter without benzalkonium [242]. Studies have shown that heparin-bonded catheters reduce risk of thrombosis and risk of CRBSI [239, 241-243]; but are less effective at reducing catheter colonization than catheters impregnated with chlorhexidine/silver sulfadiazine [244]. Unfortunately, heparin-induced thrombocytopenia can occur and has prompted many clinicians to avoid heparin [245]. Trisodium citrate has been recommended as a catheter lock solution because it possesses both anticoagulant and antimicrobial properties [223]. In a prospective, randomized,

double blind study in hemodialysis patients, use of interdialytic heparin (5,000 U/mL) was associated with a significantly greater rate of CRBSIs compared to use of 30% trisodium citrate (4.1 BSI/1,000 CVC days vs. 1.1BSI/1,000 CVC days [246].

Warfarin has been evaluated as a means to reduce CVC thrombus formation and, hence, infection [247-251]. However, other studies have not confirmed reduced thrombosis and others have found untoward interactions in patients receiving 5-FU [252, 253]. Data are quite limited; and although low dose warfarin decreases the risk of thrombus formation in cancer patients, it has not been shown to reduce infectious complications. Over 20% of patients in some studies develop prolonged prothrombin times and required dosage adjustment [254]. Other anticoagulants, such as factor Xa inhibitors or direct thrombin inhibitors, have not been adequately assessed in terms of reducing the risk of catheter-associated infection.

Replacement of Peripheral and Midline Catheters

Recommendations

1. Replace peripheral catheters every 72-96 hours to reduce risk of infection and phlebitis in adults. Category 1B

2. Replace peripheral catheters in children only when clinically indicated [82, 83]. Category 1B

2. Replace midline catheters only when there is a specific indication. Category II

Background

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

826 catheters increases when catheters are left in place >72 hours [83, 255, 256]. However,
827 rates of phlebitis are not substantially different in peripheral catheters left in place 72
828 hours compared with 96 hours [257]. Because phlebitis and catheter colonization have
829 been associated with an increased risk for catheter-related infection, short peripheral
830 catheter sites commonly are replaced at 72-96 hour intervals to reduce both the risk for
831 infection and patient discomfort associated with phlebitis.

832 Midline catheters are associated with lower rates of phlebitis than short peripheral
833 catheters and with lower rates of infection than CVCs [258-260]. In one prospective
834 study of 140 midline catheters, their use was associated with a BSI rate of 0.8 per 1,000
835 catheter days [260]. No specific risk factors, including duration of catheterization, were
836 associated with infection. Midline catheters were in place a median of 7 days, but for as
837 long as 49 days. Although the findings of this study suggested that midline catheters
838 could be changed only when there is a specific indication, no prospective, randomized
839 studies have assessed the benefit of routine replacement as a strategy to prevent CRBSI
840 associated with midline catheters.

841 **Replacement of CVCs, Including PICCs and Hemodialysis Catheters**

842 **Recommendations**

843 1. Do not routinely replace CVCs, PICCs, hemodialysis catheters, or pulmonary artery
844 catheters to prevent catheter-related infections. Category IB

845 2. Do not remove CVCs or PICCs on the basis of fever alone. Use clinical judgment
846 regarding the appropriateness of removing the catheter if infection is evident elsewhere or
847 if a noninfectious cause of fever is suspected. Category II

3. Do not use guidewire exchanges routinely for non-tunneled catheters to prevent infection. Category IB

4. Do not use guidewire exchanges to replace a non-tunneled catheter suspected of infection. Category IB

4. Use a guidewire exchange to replace a malfunctioning non-tunneled catheter if no evidence of infection is present. Category IB

5. Use new sterile gloves before handling the new catheter when guidewire exchanges are performed. Category II

Background

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 [261, 262]. One of these studies involved 112 surgical ICU patients needing CVCs, pulmonary artery catheters, or peripheral arterial catheters [262], whereas the other study involved only subclavian hemodialysis catheters [261]. 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 are 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 [263]. 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 [264]. 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 [25, 264]. However, in selected patients with tunneled hemodialysis catheters and bacteremia, catheter exchange over a guidewire, in combination with antibiotic therapy, is an alternative as a salvage strategy in patients with limited venous access [265-268].

Because of the increased difficulty obtaining vascular access 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 [121]. In addition, no relation was found between duration of catheterization and the daily probability of infection ($r = 0.21$; $p > 0.1$), suggesting that routine replacement of CVCs likely does not reduce the incidence of catheter-related infection [121].

Vascular access sites can be even more limited among neonates. Four randomized trials (n=368) summarized in a recent Cochrane Database Systemic Review compared the effects of giving parenteral nutrition through percutaneous central venous

catheters vs. peripheral intravenous catheters. Fewer painful procedures (venopunctures) were required in neonates randomized to percutaneously placed CVCs, and there was no evidence for increased risk of BSIs [269].

CVC occlusion due to thrombus formation is one of the most common reasons for CVC removal in neonates. Various methods have been tried to prevent catheter occlusion. Recently, a randomized trial (n=201) evaluated whether a continuous heparin infusion (0.5 units/kg/hour) could effectively prolong the duration of catheterization when compared to a placebo infusion. The rate of catheter occlusion requiring catheter removal was lower in the heparin group (6% vs. 31%, P=0.001: NNT=4). Rates of CRBSI were similar, although the study was not powered to evaluate CRBSI rate differences. Heparin associated antibody levels were not routinely measured [270].

Hemodialysis Catheters

The use of catheters for hemodialysis is the most common factor contributing to bacteremia in dialysis patients [271, 272]. The relative risk for bacteremia in patients with dialysis catheters is sevenfold the risk for patients with arteriovenous (AV) fistulas [273]. To reduce the rate of infection, 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 a non-cuffed catheter, even in the ICU setting, if the catheter is expected to stay in place for >3 weeks [198].

Pulmonary Artery Catheters

Pulmonary artery catheters are inserted through a polytetrafluoroethylene 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 [240]. Meta-analysis indicates that the CRBSI rate associated with pulmonary artery catheterization is 3.7 per 1,000 catheter days and somewhat higher than the rate observed for unmedicated and non-tunnelled CVCs (2.7 per 1,000 catheter days)[6, 93].

Data from prospective studies indicate that the risk of significant catheter colonization and CRBSI increases the longer the catheter remains in place. In general, the risk of significant catheter colonization increases after 4 days of catheterization [137, 274, 275], whereas the risk of CRBSI increases beyond 5-7 days of catheterization [137, 146, 276]. Efforts must be made to differentiate between infection related to the introducer and that related to the pulmonary artery catheter. Significant colonization of the introducer occurs earlier than that of the pulmonary artery catheter [274, 277]. However, no studies indicate that catheter replacement at scheduled time intervals is an effective method to reduce CRBSI [262, 264, 277]. In patients who continue to require hemodynamic monitoring, pulmonary artery catheters do not need to be changed more frequently than every 7 days [277]. 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 ($p = 0.002$) [138].

Umbilical Catheters

Recommendations

1. Remove and do not replace umbilical artery catheters if any signs of CRBSI, vascular insufficiency, or thrombosis are present [278]. Category II

2. Remove and do not replace umbilical venous catheters if any signs of CRBSI or thrombosis are present [278]. Category II

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

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

5. Cleanse the umbilical insertion site with an antiseptic 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 [279-283]. Category IB

6. Do not use topical antibiotic ointment or creams on umbilical catheter insertion sites because of the potential to promote fungal infections and antimicrobial resistance [150, 151]. Category IA

7. Add low doses of heparin (0.25-1.0 U/ml) to the fluid infused through umbilical arterial catheters [284-286]. Category IB

8. 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 [278, 287]. Category II

9. 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 [288, 289]. Category II

Background

Although the umbilical stump becomes heavily colonized soon after birth, umbilical vessel catheterization often is used for vascular access in newborn infants.

963 Umbilical vessels can be cannulated easily and permit both collection of blood samples
964 and measurement of hemodynamic status. The incidences of catheter colonization and
965 BSI are similar for umbilical vein catheters and umbilical artery catheters. In several
966 studies, an estimated 40%-55% of umbilical artery catheters were colonized and 5%
967 resulted in CRBSI; umbilical vein catheters were associated with colonization in 22%-
968 59% of cases [280, 281, 290] and with CRBSI in 3%-8% of cases [281]. Although
969 CRBSI rates are similar for umbilical catheters in the high position (i.e., above the
970 diaphragm) compared with the low position (i.e., below the diaphragm and above the
971 aortic bifurcation), catheters placed in the high position result in a lower incidence of
972 vascular complications without an increase in adverse sequelae [281].

973 Risk factors for infection differ for umbilical artery and umbilical vein catheters.
974 In one study, neonates with very low birth weight who also received antibiotics for >10
975 days were at increased risk for umbilical artery CRBSIs [281]. In comparison, those with
976 higher birth weight and receipt of parenteral nutrition fluids were at increased risk for
977 umbilical vein CRBSI. Duration of catheterization was not an independent risk factor for
978 infection of either type of umbilical catheter.

979 A recent randomized trial (n=210) evaluated whether long-term umbilical venous
980 catheterization (up to 28 days) would result in the same or fewer CABSIs when compared
981 to neonates who were randomized to short-term umbilical venous catheterization for 7-10
982 days followed by percutaneous central venous catheterization. CABSI rate was higher
983 (20%) among long term catheterized neonates when compared to short term catheterized
984 neonates (13%). The difference was not statistically significant (P=0.17), although the
985 study was underpowered to evaluate differences in venous thrombosis rates [291].

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

Recommendations

1. In adults, use of the radial, brachial or dorsalis pedis sites is preferred over the femoral or axillary sites of insertion to reduce the risk of infection [94, 95, 292, 293]. Category IB

2. In children, the brachial site should not be used. The radial, dorsalis pedis, and posterior tibial sites are preferred over the femoral or axillary sites of insertion [94]. Category II

3. A cap, mask, sterile gloves and a large sterile fenestrated drape should be used during peripheral arterial catheter insertion [95, 293]. Category IB

4. During axillary or femoral artery catheter insertion, maximal sterile barriers precautions should be used. Category II

5. Replace arterial catheters only when there is a clinical indication. Category II

6. Remove the arterial catheter as soon as it is no longer needed. Category II

7. Use disposable, rather than reusable, transducer assemblies when possible [294-298]. Category IB

8. Do not routinely replace arterial catheters to prevent catheter-related infections [262, 276, 299, 300]. Category II

9. 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 [25, 295]. Category IB

10. Keep all components of the pressure monitoring system (including calibration devices and flush solution) sterile [294, 301-303]. Category IA

11. 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 [297, 304]. Category II

12. 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 [297]. Category IA

13. Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit [297, 305, 306]. Category IA

14. Sterilize reusable transducers according to the manufacturers' instructions if the use of disposable transducers is not feasible [297, 305-308]. Category IA

Background

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 lower than that of short term, uncuffed, non-coated, non-tunneled CVCs (1.7 versus 2.7 per 1,000 catheter days)[6]. However, CRBSI rates are comparable between arterial catheters and short term, uncuffed, medicated, non-tunneled CVCs [6]. Unlike CVCs, use of full barrier precautions during arterial cannulaton does not appear to reduce the risk of arterial CRBSI [293, 309]. Nonetheless, when arterial catheters are inserted using a protocol which includes maximum barrier precautions, a very low rate of CRBSI (0.41/1,000 catheter days) can be achieved[95]. Although a meta-analysis failed to discern a difference in rates of CRBSI among three sites of insertion (radial, femoral, and axillary)[310], colonization of catheters inserted in the femoral site occurs more often

[293]. In addition, a prospective observational study of over 2,900 arterial catheters that were inserted using maximum barrier precautions demonstrated an almost 8-fold increase in the incidence of CRBSI when the femoral site was used compared to the radial site[311]. Furthermore, there is a greater risk of CRBSI caused by Gram-negative bacteria when the femoral site is utilized [311]. The rates of catheter colonization and CRBSI appear similar between the radial and dorsalis pedis sites[292]. The risk of developing a CRBSI increases with the duration of catheterization [276, 312]; however, the routine changing of arterial catheters at scheduled times does not result in a diminution of the rate of CRBSI [262]. Catheters that need to be in place for >5 days should not be routinely changed if no evidence of infection is observed.

Replacement of Administration Sets

Recommendations

1. In patients not receiving blood, blood products or lipid emulsions, replace administration sets, including secondary sets and add-on devices, no more frequently than at 96-hour intervals, [313] but at least every 7 days [255, 314-316]. 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 [317-320]. Category IB
3. Replace tubing used to administer propofol infusions every 6 or 12 hours, when the vial is changed, per the manufacturer's recommendation (FDA website Medwatch) [321]. Category IA

Background

The optimal interval for routine replacement of IV administration sets has been examined in a number of well-controlled studies and meta-analyses. Data from these studies reveal that replacing administration sets no more frequently than 72-96 hours after initiation of use is safe and cost-effective [255, 257, 313, 315, 316]. More recent studies suggest that administration sets may be used safely for up to 7 days if used in conjunction with antiseptic catheters or if fluids that enhance microbial growth (e.g., parenteral nutrition or blood) have not been used [30, 322]. When a fluid that enhances microbial growth is infused (e.g., lipid emulsions and blood products), more frequent changes of administration sets are indicated as these products have been identified as independent risk factors for CRBSI [30, 317, 323-327].

Needleless Intravascular Catheter Systems

Recommendations

1. Change the needleless components at least as frequently as the administration set. There is no benefit to changing these more frequently than every 72 hours [87, 328-334]. Category II

2. Change caps no more frequently than every 72 hours for the purpose of reduced infection rates or according to manufacturers' recommendations[328, 330, 333, 334]. Category II

3. Ensure that all components of the system are compatible to minimize leaks and breaks in the system[335]. Category II

4. Minimize contamination risk by wiping the access port with an appropriate antiseptic (chlorhexidine preferred) and accessing the port only with sterile devices [330, 333, 335]. Category IA

5. Use a needleless system to access IV tubing. Category IC

6. When needleless systems are used, the split septum valve is preferred over the mechanical valve due to increased risk of infection [336-339]. Category II

Background

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 common, 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. Nonetheless, stopcocks should be capped when not being used.

"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 [340].

Attempts to reduce the incidence of sharp injuries and the resultant risk for transmission of bloodborne infections to healthcare personnel have led to the design and introduction of needleless infusion systems. There are several types of needleless connectors on the market.

The first type of needleless system connectors consisted of a split septum cap, which is accessed with a blunt cannula instead of a needle. Because of the large amount of space in the hub to accommodate the cannula, blood can easily backup into this space and occlude the catheter. A luer-activated device, which incorporates a valve preventing the outflow of fluid through the connector, was designed to eliminate this problem. Some luer devices require a cap to be attached to the valve when not in use, which can be difficult to maintain aseptically, and therefore they may be prone to contamination.

Another type of second-generation needleless system addressed the occlusion issue by incorporating positive pressure or neutral displacement to either flush out aspirated blood or prevent its aspiration into infusion catheters. However, with the positive pressure the risk of occlusion may actually rise, as the valves are held open, allowing retrograde blood flow into the catheters.

Many studies have shown that when the devices are used according to manufacturers' recommendations (i.e., appropriate disinfection prior to access*)*, they do not substantially affect the incidence of CRBSI [328-335]. Use of “second-generation” needleless connectors or positive pressure mechanical valves, which reduce the backflow of blood after it is disengaged, appear to be effective in reducing hub colonization in some [341-343], but not all studies [344]. In one study [341], the incidence of CRBSI was reduced when the needleless connector was compared to standard stopcocks. Appropriate disinfectants must be used to prevent transmission of microbes through connectors [345]. Disinfection of the devices with chlorhexidine/alcohol solutions appears to be most effective in reducing colonization [342]. However, reports continue

to be published of outbreaks of CRBSI, even when the second-generation connectors are used [336-339]. The physical and mechanical properties of second-generation connectors vary widely from device to device. Potential explanations for outbreaks associated with these devices include difficulty encountered in adequate disinfection of the surface of the connector due to physical characteristics of the plastic housing diaphragm interface, fluid flow properties (laminar vs. turbulent), internal surface area, potential fluid dead space, inadequate flushing of the device due to poor visualization of the fluid flow pathway in opaque devices, and the presence of internal corrugations that could harbor organisms, particularly if the catheters are used to access blood [338]. Additionally, a silver coated connector valve has been approved for marketing. However, there are no published randomized trials with this device and no recommendation can be made regarding its use. Likewise, an antiseptic-barrier cap has been studied in a laboratory setting and appears to be effective in preventing the entry of microorganisms [346], but has not yet been studied in a clinical trial.

Multidose Parenteral Medication Vials and Parenteral Fluids

Recommendations

1. Mix all routine parenteral fluids in the pharmacy in a laminar flow hood using aseptic technique [347, 348]. Category IB

2. Do not use any container of parenteral fluid that has visible turbidity, leaks, cracks, particulate matter, or if the manufacturer's expiration date has passed [348]. Category IB

3. Use single dose vials for parenteral additives or medications when possible [348, 349]. Category II

4. Do not combine the leftover content of single use vials for later use [348, 349]. Category IA

5. If multidose vials are used, refrigerate multidose vials after they are opened if recommended by the manufacturer [348]. Category II

6. Cleanse the access diaphragm of multidose vials with 70% alcohol before inserting a device into the vial [350]. Category IA

7. Use a sterile device to access a multidose vial and avoid touch contamination of the device before penetrating the access diaphragm [351, 352]. Category IA

8. Discard multidose vial if sterility is compromised [351, 352]. Category IA

9. All multidose vials should be dated when 1st used and thereafter not used beyond the manufacturer's stated expiration period. Category IC

10. Use the needle and syringe to access the multidose vial only once and to then discard both safely. This applies to each and every dose withdrawn from the vial [351, 352]. Category IA

11. Complete the infusion of lipid-containing solutions (e.g., 3-in-1 solutions) within 24 hours of hanging the solution [317, 318, 326, 327, 353]Category IB

12. 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 [317, 326, 327]. Category IB

13. Complete infusions of blood or other blood products within 4 hours of hanging the blood[354-357]. Category II

14. No recommendation can be made for the hang time of other parenteral fluids. Unresolved issue

Background

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 [358], the consequences of contamination might result in life threatening infection [359-361]}.Risk of contamination must be minimized by using one needle and one syringe one time only. Simply changing the needle and using the same syringe to access the vial is an unacceptable practice. Single use vials are intended for single use only (one puncture). They are frequently preservative free and pose a risk for contamination if they are punctured several times. This is particularly true with propofol, a drug that readily supports the growth of bacteria once contaminated.

Performance Improvement

Recommendation

Use hospital-specific or collaborative-based performance improvement initiatives in which multifaceted strategies are "bundled" together improve compliance with evidence-based recommended practices [61, 108, 109, 362-366]. Category 1B

Background

Clinical decision makers, healthcare payers, and patient safety advocates emphasize the importance of translating research findings into everyday practice. Rigorous evaluations of CRBSI preventive practices using study designs with high internal validity and including study populations that optimize external validity remain necessary. Once practices have been determined to be effective and economically efficient, the next step is to implement these evidence-based practices so they become

part of routine clinical care. Unfortunately, the use of evidence-based CRBSI preventive practices in U.S. hospitals remains suboptimal [367, 368]. In a national survey conducted in March 2005 of over 700 U.S. hospitals, approximately one quarter of U.S. hospitals indicated that either maximal sterile barrier precautions during central line insertion or chlorhexidine gluconate as site disinfectant, two practices widely recommended to prevent CRBSI, were not being used routinely [369]. Approximately 15% of U.S. hospitals reported routinely changing CVCs to prevent infection despite evidence that this practice should no longer be used [368, 369].

Accordingly, investigators have attempted various approaches to better translate research findings and evidence-based recommendations into clinical practice. Numerous quality improvement studies have been published during the past several years that have used various methods, such as education of healthcare personnel, audit and feedback, organizational change, and clinical reminders [54-57, 108, 109, 363, 370-372]. The educational interventions, for example, primarily targeted hand hygiene, use of maximal sterile barriers during insertion, appropriate insertion site selection, proper site care using chlorhexidine gluconate, and prompt removal of unnecessary catheters. While a large number of before-and-after studies with a few using concurrent control groups [61, 109] have been published, no randomized, controlled trial evaluating a quality improvement strategy to prevent CRBSI has been reported [373]. The vast majority of before-and-after studies reported statistically significant decreases in CRBSI rates after a quality improvement strategy was implemented [373]. Additionally, both controlled trials also found statistically significant reductions of CRBSI in the intervention units compared to control units [61, 109].

Investigators have also employed multifaceted approaches in which several strategies are bundled together to improve compliance with evidence-based guidelines [61, 108, 109]. One such collaborative cohort study [108] of 108 ICUs in Michigan targeted clinicians' use of five evidence-based practices: hand hygiene, maximum barrier precautions, chlorhexidine site disinfection, avoiding the femoral site, and removing unnecessary central venous catheters. In addition to educating clinicians about CRBSI prevention, interventions used included: 1) a central venous catheter cart that contained all the necessary supplies; 2) a checklist to ensure adherence to proper practices; 3) stoppage of procedures in non-emergent situations, if evidence-based practices were not being followed; 4) prompt removal of central catheters during daily patient rounds; 5) feedback to the clinical teams regarding the number of CRBSI episodes and overall rates; and 6) buy-in from the chief executive officers of the participating hospitals that chlorhexidine gluconate products/solutions would be stocked prior to study initiation. Using an interrupted time series design and multivariable regression, the investigators reported a statistically significant 66% decrease in CRBSI rates approximately 18 months after the intervention began [108]. Specific process and outcome measures for tracking and feedback (i.e. rate of central line infections, proportion of central lines placed with all or individual bundle elements performed AND documented) should be identified in individual institutions based on areas that have been identified for performance improvement.

Finally, emphasis on the care and maintenance of catheters once they are in place should be a focus of performance improvement and quality assurance in all programs. A study to assess practice and staff knowledge of CVC post-insertion care and identify

aspects of CVC care with potential for improvement revealed several areas of opportunity to improve post-insertion care [374]. Rates of breaches in catheter care and CRBSIs were calculated and statistical significance assumed when $P<0.05$. Data were recorded from 151 CVCs in 106 patients giving a total of 721 catheter days. In all, 323 breaches in care were identified giving a failure rate of 44.8%, with significant differences between intensive care unit (ICU) and non-ICU wards ($P<0.001$). Dressings (not intact) and caps and taps (incorrectly placed) were identified as the major lapses in CVC care with 158 and 156 breaches per 1000 catheter days, respectively. Interventions to improve reliability of care should focus on making the implementation of best practice easier to achieve.

Table 1. Catheters used for venous and arterial access.

Catheter Type	Entry Site	Length	Comments
Peripheral venous catheters	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, axillary, brachial, posterior tibial arteries	less than 3 inches	low infection risk
Midline catheters	inserted via the antecubital fossa into the proximal basilic or cephalic veins	3 to 8 inches	anaphylactoid reactions have been reported with catheters made of elastomeric hydrogel; does not enter central veins; 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 CRBSI
Pulmonary artery	inserted through a Polytetrafluoroethylene usually heparin bonded; similar introducer in a central vein (subclavian, internal jugular, or femoral)	depending on patient size	30 cm or longer rates of bloodstream infection as CVC; 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 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 CRBSI; improved patient self-image; no need for local catheter site care; surgery required for catheter removal
Umbilical catheters	inserted into either umbilical	6 cm or less, depending	risk for CRBSI similar with

vein or umbilical artery on patient size catheters placed in umbilical vein vs. artery

TABLE 2. Pooled means and key percentile of the distribution of central-line associated bloodstream in infection rates among hospitals participating in the National Healthcare Safety Network, CDC, 2006 –2007. [15]

Type of Intensive care Unit	No. Units	No. CABSIs	Catheter-days	Pooled mean/ 1,000 catheter-days	Percentile				
					10%	25%	50%	75%	90%
Burn	22	239	42452	5.6	0	1.5	3.8	8.2	13.5
Coronary	121	373	181079	2.1	0	0	1.3	2.8	5.3
Surgical cardiothoracic	97	397	275194	1.4	0	0	1.2	1.9	3.4
Medical	144	1073	454839	2.4	0	0.6	1.9	3.6	5.3
Medical/surgical Major teaching	104	692	342214	2.0	0	0.5	1.5	3.0	4.2
Med/Surg All others	343	972	662489	1.5	0	0	0.6	2.0	3.6
Pediatric medical/surgical	71	404	140,848	2.9	0.0	0.0	2.1	3.8	6.0
Neurologic	15	31	25440	1.2	-	-	-	-	-
Neurosurgical	39	173	68550	2.5	0	0	1.9	3.8	6.2
Surgical	128	881	383126	2.3	0	0.5	1.7	3.1	5.1
Trauma	32	435	107620	4.0	0.3	1.5	4.0	5.7	7.7
Inpatient medical ward	40	111	60257	1.8	0	0	0	2.2	3.4
Inpatient medical/surgical ward	82	169	132133	1.3	0	0	0	1.6	4.0

Table 3. Pooled means and key percentiles for the distribution of central-line associated bloodstream infection rates for level III NICUs, NHSH, CDC, 2006-2007.[15]

Birth-weight category	No. units	No. CLABSI	Central line-days	Pooled mean	Percentile				
					10%	25%	50%	75%	90%
≤ 750 g	82	225	60850	3.7	0.0	0.0	2.3	4.9	9.0
751-1000 g	84	185	55445	3.3	0.0	0.0	2.4	4.5	7.3
1001-1500 g	83	144	55874	2.6	0.0	0.0	1.6	3.6	6.1
1501-2500 g	71	105	44402	2.4	0.0	0.0	1.1	3.3	6.0
>2500 g	61	87	42611	2.0	0.0	0.0	0.0	3.1	5.4

TABLE 3. Most common pathogens isolated from nosocomial bloodstream infections, SCOPE. [16, 17]

	Percentage of BSIs		
Pathogen	Total	ICU	Non-ICU
Coagulase-negative staphylococci	31.3	35.9	26.6
Staphylococcus aureus	20.2	16.8	23.7
Enterococcus spp.	9.4	9.8	9.0
Candida spp.	9.0	10.1	7.9
Gram-negative rods			
Escherichia coli	5.6	3.7	7.6
Klebsiella spp	4.8	4.0	5.5
Enterobacter spp.	4.3	4.7	3.8
Pseudomonas aeruginosa	3.9	4.7	3.1
Acinetobacter baumannii	1.7	2.1	1.3
Serratia spp.	1.3	1.6	0.9

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Appendix C. Summary Recommendations

Strategies for Prevention of Catheter-Related Infections in Adult and Pediatric Patients

Education, training and staffing

Recommendations

1. Educate healthcare personnel 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 [53-61]. Category IA

2. Periodically assess knowledge of and adherence to guidelines for all persons who are involved in the insertion and maintenance of intravascular catheters [53-61]. Category IA

3. Designate only trained personnel who demonstrate competence for the insertion and maintenance of peripheral and central intravascular catheters. [60-74]. Category IA

4. Ensure appropriate nursing staff levels in ICUs to minimize the incidence of catheter-related BSIs. Observational studies suggest a ratio of 2:1 in ICUs where nurses are managing patients with CVCs [75-77]. Category IB

Site selection

Recommendations for peripheral catheters and midline catheters

1. In adults, use an upper-extremity site for catheter insertion. Replace a catheter inserted in a lower extremity site to an upper extremity site as soon as possible [82, 83]. Category IB

2. In pediatric patients, the upper or lower extremities or the scalp can be used as the catheter insertion site [82, 83]. Category II

3. Select catheters on the basis of the intended purpose and duration of use, known infectious and non-infectious complications (e.g., phlebitis and infiltration), and experience of individual catheter operators [83-85]. Category IB

4. Avoid the use of steel needles for the administration of fluids and medication that might cause tissue necrosis, if extravasation occurs [83-85]. Category IA

5. Use a midline catheter or peripherally inserted central catheter (PICC), instead of a short peripheral catheter, when the duration of IV therapy will likely exceed six days [83-85]. Category IB

Recommendations for central venous catheters

6. Weigh the risk and benefits of placing a central venous 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) [25, 86-101]. Category IA

7. Use a subclavian site, rather than a jugular or a femoral site, in adult patients to minimize infection risk for nontunneled CVC placement [25, 99, 100]. Category IA

8. No recommendation can be made for a preferred site of insertion to minimize infection risk for a tunneled CVC. Unresolved issue

9. Place catheters used for hemodialysis and pheresis in a jugular or femoral vein, rather than a subclavian vein, to avoid venous stenosis [101-105]. Category IA

10. Use ultrasound guidance to place central venous catheters to reduce the number of cannulation attempts and mechanical complications if this technology is available [106, 107]. Category 1B

11. Promptly remove any intravascular catheter that is no longer essential [108, 109]. Category IA

Hand Hygiene and Aseptic Technique

Recommendations

1. Perform hand hygiene procedures, either by washing hands with conventional antiseptic containing soap and water or with waterless alcohol-based hand rubs (ABHR). Hand hygiene should be performed 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 [58, 127-131]. Category IA

2. Maintain aseptic technique for the insertion and care of intravascular catheters [25, 132-134]. Category IA

3. Wear clean gloves, rather than sterile gloves, for the insertion of peripheral intravascular catheters, if the access site is not touched after the application of skin antiseptics. Category IC

4. Sterile gloves should be worn for the insertion of arterial, central, and midline catheters [25, 132-134]; and these gloves should be changed, if a catheter is being exchanged over a guidewire (thereby contaminating the gloves) and a new sterile catheter is then handled. Category IA

4. Wear either clean or sterile gloves when changing the dressing on intravascular catheters. Category IC

Maximal Sterile Barrier Precautions

Recommendations

1. Use maximal sterile barrier precautions, including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile full body drape, for the insertion of CVCs, PICCs, or guidewire exchange [60, 132, 136, 137]. Category IB

2. Use a sterile sleeve to protect pulmonary artery catheters during insertion [138]. Category IB

Skin Preparation

Recommendations

1. Prepare clean skin with 70% alcohol before peripheral venous catheter insertion [139]. Category IA

2. Prepare clean skin site with a 2% chlorhexidine-based preparation before central venous catheter insertion and during dressing changes. If there is a contraindication to chlorhexidine, tincture of iodine, an iodophor, or 70% alcohol can be used as alternatives [140, 141]. Category IA

3. No recommendation can be made for the safety or efficacy of chlorhexidine in infants aged <2 months. Unresolved issue

4. Allow povidone iodine to remain on the skin for at least 2 minutes or longer for the antibacterial properties to take effect, if it is not yet dry before catheter insertion. The antibacterial properties of chlorhexidine work on contact, and chlorhexidine does not

require a minimum 2- minute drying time before proceeding. Catheter insertion may begin as soon as the chlorhexidine is dry[140, 141]. Category IB

Catheter site dressing regimens

Recommendations

1. Use either sterile gauze or sterile, transparent, semi-permeable dressing to cover the catheter site [146-149]. Category IA

2. If the patient is diaphoretic or if the site is bleeding or oozing, use gauze dressing until this is resolved [146-149]. Category II

3. Replace catheter site dressing if the dressing becomes damp, loosened, or visibly soiled [146, 147]. Category IB

4. Do not use topical antibiotic ointment or creams on insertion sites, except for dialysis catheters, because of their potential to promote fungal infections and antimicrobial resistance [150, 151]. Category IB

5. Do not submerge the catheter or catheter site in 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) [152, 153]. Category II

6. 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 dislodging the catheter may outweigh the benefit of changing the dressing [149]. Category IB

7. Replace dressings used on tunneled or implanted CVC sites no more than once per week, until the insertion site has healed [149]Category IB

8. 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

9. Ensure that catheter site care is compatible with the catheter material [154, 155]. Category IB

10. Use a sterile sleeve for all pulmonary artery catheters [138]. Category IB

11. Use a chlorhexidine-impregnated sponge dressing for temporary short-term catheters in patients older than 2 months of age, if the CRBSI rate is higher than the institutional goal, despite adherence to basic CRBSI prevention measures, including education and training, use of chlorhexidine for skin antisepsis, and MSB [22, 156-158]. Category 1B

Patient Cleansing

Recommendation

Use a 2% chlorhexidine wash daily to reduce CRBSI [162]. Category II

Catheter Securement Devices

Recommendation

Use a sutureless securement device to reduce the risk of infection for PICCs [163]. Category II

Antimicrobial/Antiseptic Impregnated Catheters and Cuffs

Recommendation

Use a chlorhexidine/silver sulfadiazine or minocycline/rifampin -impregnated CVC in adults whose catheter is expected to remain in place >5 days if, after successful implementation of a comprehensive strategy to reduce rates of CRBSI, the CRBSI rate remains above the goal set by the individual institution based on benchmark rates (Tables 2 and 3) and local factors. The comprehensive strategy should include at least 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. Category IA

Systemic Antibiotic Prophylaxis

Recommendation

Do not administer systemic antimicrobial prophylaxis routinely before insertion or during use of an intravascular catheter to prevent catheter colonization or CRBSI [188]**.** Category IA

Antibiotic Lock Prophylaxis, Antimicrobial Catheter Flush and Catheter Lock Prophylaxis

Recommendation

Use prophylactic antimicrobial lock solution in patients with long term catheters who have a history of multiple CRBSI despite optimal maximal adherence to aseptic technique [23, 211-228]. Category II

Anticoagulants

Recommendation

Do not routinely use anticoagulant therapy to reduce the risk of catheter-related infection in general patient populations [234]. Category II

Replacement of Peripheral and Midline Catheters

Recommendations

1. Replace peripheral catheters every 72-96 hours to reduce risk of infection and phlebitis in adults. Category 1B

2. Replace peripheral catheters in children only when clinically indicated [82, 83].

Category 1B

2. Replace midline catheters only when there is a specific indication. Category II

Replacement of CVCs, Including PICCs and Hemodialysis Catheters

Recommendations

1. Do not routinely replace CVCs, PICCs, hemodialysis catheters, or pulmonary artery catheters to prevent catheter-related infections. Category IB

2. 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. Category II

3. Do not use guidewire exchanges routinely for non-tunneled catheters to prevent infection. Category IB

4. Do not use guidewire exchanges to replace a non-tunneled catheter suspected of infection. Category IB

4. Use a guidewire exchange to replace a malfunctioning non-tunneled catheter if no evidence of infection is present. Category IB

5. Use new sterile gloves before handling the new catheter when guidewire exchanges are performed. Category II

Umbilical Catheters

Recommendations

1. Remove and do not replace umbilical artery catheters if any signs of CRBSI, vascular insufficiency, or thrombosis are present [278]. Category II

2. Remove and do not replace umbilical venous catheters if any signs of CRBSI or thrombosis are present [278]. Category II

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

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

5. Cleanse the umbilical insertion site with an antiseptic 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 [279-283]. Category IB

6. Do not use topical antibiotic ointment or creams on umbilical catheter insertion sites because of the potential to promote fungal infections and antimicrobial resistance [150, 151]. Category IA

7. Add low doses of heparin (0.25-1.0 U/ml) to the fluid infused through umbilical arterial catheters [284-286]. Category IB

8. 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 [278, 287]. Category II

9. 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 [288, 289]. Category II

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

Recommendations

1. In adults, use of the radial, brachial or dorsalis pedis sites is preferred over the femoral or axillary sites of insertion to reduce the risk of infection [94, 95, 292, 293]. Category IB

2. In children, the brachial site should not be used. The radial, dorsalis pedis, and posterior tibial sites are preferred over the femoral or axillary sites of insertion [94]. Category II

3. A cap, mask, sterile gloves and a large sterile fenestrated drape should be used during peripheral arterial catheter insertion [95, 293]. Category IB

4. During axillary or femoral artery catheter insertion, maximal sterile barriers precautions should be used. Category II

5. Replace arterial catheters only when there is a clinical indication. Category II

6. Remove the arterial catheter as soon as it is no longer needed. Category II

7. Use disposable, rather than reusable, transducer assemblies when possible [294-298]. Category IB

8. Do not routinely replace arterial catheters to prevent catheter-related infections [262, 276, 299, 300]. Category II

9. 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 [25, 295]. Category IB

10. Keep all components of the pressure monitoring system (including calibration devices and flush solution) sterile [294, 301-303]. Category IA

11. 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 [297, 304]. Category II

12. 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 [297]. Category IA

13. Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit [297, 305, 306]. Category IA

14. Sterilize reusable transducers according to the manufacturers' instructions if the use of disposable transducers is not feasible [297, 305-308]. Category IA

Replacement of Administration Sets

Recommendations

1. In patients not receiving blood, blood products or lipid emulsions, replace administration sets, including secondary sets and add-on devices, no more frequently than at 96-hour intervals, [313] but at least every 7 days [255, 314-316]. 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 [317-320]. Category IB

3. Replace tubing used to administer propofol infusions every 6 or 12 hours, when the vial is changed, per the manufacturer's recommendation (FDA website Medwatch) [321]. Category IA

Needleless Intravascular Catheter Systems

Recommendations

1. Change the needleless components at least as frequently as the administration set. There is no benefit to changing these more frequently than every 72 hours [87, 328-334]. Category II

2. Change caps no more frequently than every 72 hours for the purpose of reduced infection rates or according to manufacturers' recommendations[328, 330, 333, 334]. Category II

3. Ensure that all components of the system are compatible to minimize leaks and breaks in the system[335]. Category II

4. Minimize contamination risk by wiping the access port with an appropriate antiseptic (chlorhexidine preferred) and accessing the port only with sterile devices [330, 333, 335]. Category IA

5. Use a needleless system to access IV tubing. Category IC

6. When needleless systems are used, the split septum valve is preferred over the mechanical valve due to increased risk of infection [336-339]. Category II

Multidose Parenteral Medication Vials and Parenteral Fluids

Recommendations

1. Mix all routine parenteral fluids in the pharmacy in a laminar flow hood using aseptic technique [347, 348]. Category IB

2. Do not use any container of parenteral fluid that has visible turbidity, leaks, cracks, particulate matter, or if the manufacturer's expiration date has passed [348]. Category IB

3. Use single dose vials for parenteral additives or medications when possible [348, 349]. Category II

4. Do not combine the leftover content of single use vials for later use [348, 349]. Category IA

5. If multidose vials are used, refrigerate multidose vials after they are opened if recommended by the manufacturer [348]. Category II

6. Cleanse the access diaphragm of multidose vials with 70% alcohol before inserting a device into the vial [350]. Category IA

7. Use a sterile device to access a multidose vial and avoid touch contamination of the device before penetrating the access diaphragm [351, 352]. Category IA

8. Discard multidose vial if sterility is compromised [351, 352]. Category IA

9. All multidose vials should be dated when 1st used and thereafter not used beyond the manufacturer's stated expiration period. Category IC

10. Use the needle and syringe to access the multidose vial only once and to then discard both safely. This applies to each and every dose withdrawn from the vial [351, 352]. Category IA

11. Complete the infusion of lipid-containing solutions (e.g., 3-in-1 solutions) within 24 hours of hanging the solution [317, 318, 326, 327, 353]Category IB

12. 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 [317, 326, 327]. Category IB

13. Complete infusions of blood or other blood products within 4 hours of hanging the blood[354-357]. Category II

14. No recommendation can be made for the hang time of other parenteral fluids.

Unresolved issue

Performance Improvement

Recommendation

Use hospital-specific or collaborative-based performance improvement initiatives in which multifaceted strategies are "bundled" together improve compliance with evidence-based recommended practices [61, 108, 109, 362-366]. Category 1B

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