Preventable Health Care–Associated Infections in Pediatric Critical Care

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Abstract

Keywords

- infection
- nosocomial
- ventilator-associated pneumonia
- surgical site infections
- catheter-related infection

Health care–associated infections (HAIs) account for a substantial portion of health care–acquired conditions that harm patients receiving medical care in the acute care setting. In this review, we will focus on four common HAIs: central line–associated bloodstream infections, ventilator-associated pneumonia, surgical site infections, and catheter-associated urinary tract infections. The Centers for Disease Control and Prevention Web site provides additional detailed definitions and reporting criteria for each HAI. Integral to the definition of an HAI is the timing of the infection in relation to the placement of the indwelling device or surgical incision. Valid and reliable surveillance data are necessary to assess the effectiveness of prevention strategies and provide interfacility comparisons, and for pay-for-performance programs. The bundle concept, which utilizes a small set of evidence-based interventions, is integral to the prevention of HAIs.

Introduction

Health care–associated infections (HAIs) account for a substantial portion of health care–acquired conditions that harm patients receiving medical care. Nearly 1 in every 20 hospitalized patients in the United States each year acquires an HAI. In 2009, the U.S. Department of Health and Human Services developed a national HAI action plan, which targeted on central line–associated bloodstream infection (CLABSI), catheter-associated urinary tract infection (CAUTI), surgical site infection (SSI), methicillin-resistant *Staphylococcus aureus* bloodstream infections, and *Clostridium difficile* infections in acute care hospitals.¹ In 2011, the Centers for Medicare and Medicaid Services instituted mandatory reporting requirements for specific types of HAI data through the Centers for Disease Control and Prevention's (CDC's) National Healthcare Safety Network (NHSN) in order for the hospitals to receive their full annual reimbursement, which greatly increased the data repository.¹ More than 12,500 hospitals and other health care facilities provide data to NHSN.² The NHSN is a national HAI surveillance system that utilizes standard methodology and definitions to collect data from health care facilities

within the USA; the CDC set the surveillance criteria for submission.

For the purposes of NHSN surveillance in the acute care setting, the CDC defines HAI as a localized or systemic condition resulting from an adverse reaction to the presence of an infectious agent(s) or its toxin(s). There must be no evidence that the infection was present or incubating at the time of admission to the acute care setting.^{3,4} Valid and reliable surveillance data are necessary to assess the effectiveness of prevention strategies and provide interfacility comparisons, and for pay-for-performance programs.¹

To standardize the classification of an infection as present on admission (POA) or an HAI, the following objective surveillance criteria have been adopted by NHSN. If all of the elements used to meet a CDC/NHSN site-specific infection criterion are present during the 2 calendar days before the day of admission, the first day of admission (day 1), and/or the day after admission (day 2) and are documented in the medical record, the infection is considered POA. Infections that are POA should not be reported as HAIs.⁴ The specific definitions and criteria for each HAI can be found on the CDC Web site.⁵

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With all HAIs, prevention is paramount. The Institute for Healthcare Improvement developed the “bundle” concept in 2001.⁶ They defined a bundle as a small set of evidence-based interventions for a population that, when implemented together, result in significantly better outcomes than when implemented individually.⁶ There are prevention bundles specific for each HAI. A summary of CDC recommendations is represented in ►Table 1.

HAI have many etiologies (►Table 2). For the purpose of this review, we will focus on four common HAIs: CLABSI, ventilator-associated pneumonia (VAP), SSI, and CAUTI. Estimates of HAIs occurring in acute care hospitals in the United States in 2011 are listed in ►Table 3.

Central Line–Associated Bloodstream Infections

Introduction

CLABSIs are one of the most deadly types of HAIs, with a mortality rate of 12 to 25%.⁴ An estimated 41,000 CLABSIs occur in U.S. hospitals each year.^{7,8} These infections in pediatric patients are usually serious infections typically causing a prolongation of hospital stay, increased cost of \$55,646, and increased risk of mortality.^{8,9}

Definition

The CDC defines a CLABSI as recovery of a pathogen from a blood culture (a single blood culture for organisms not commonly present on the skin and two or more blood cultures for organisms commonly present on the skin) in a patient who had a central line at the time of infection or within the 48-hour period prior to infection development. The infection cannot be related to any other infection the patient might have and must not have been present or incubating when the patient was admitted to the facility. The National Nosocomial Infections Surveillance System has also defined CLABSI in a similar manner.¹⁰

For surveillance purposes, the CDC has introduced the term laboratory-confirmed bloodstream infection.³ Laboratory-confirmed bloodstream infection must meet at least one of the following criteria: (1) patient has a recognized pathogen cultured from one or more blood cultures and the pathogen is not related to an infection at another site; (2) patient has fever, chills, and/or hypotension as well as positive laboratory cultures from two or more blood samples drawn on separate occasions, which are not related to infection at another site and do not reflect contamination; (3) patient <1 year of age has at least one of the following signs or symptoms: fever, hypothermia, apnea, or bradycardia (in addition to the above criteria).

Table 1 Center for Disease Control and Prevention health care–associated infection prevention recommendations

Central line–associated bloodstream infection	Ventilator-associated pneumonia	Surgical site infection	Catheter-associated urinary tract infection
Insertion	Daily assessment of need for continued intubation	Preoperative skin antisepsis	Insertion
Hand hygiene	Head of bed elevated 30–45 degrees	For hair removal, use electric clippers and not razors	Avoidance of unnecessary catheterization
Antiseptic scrub prior to insertion	Routine oral care	Appropriate antibiotic timing	Utilization of sterile technique
Sterile barrier and insertion technique	Maintain equipment		Maintenance
Maintenance			Daily assessment of need for catheter
Daily assessment of need for central line			Maintain hygiene
Hand hygiene and gloves when entering line or manipulating dressing			Tubing without kinks or obstructions
Antiseptic solution to entry ports prior to access			Empty bag regularly
Maintenance of a clean, dry, occlusive, sterile dressing			Avoid disconnections
			Secure catheter to leg to prevent pulling
			Collection bag below bladder to prevent backflow

Source: Adapted from Centers for Disease Control and Prevention Web site.^{18–21}

Table 2 Centers for Disease Control and Prevention’s National Healthcare Safety Network major and specific types of health care–associated infections

Major category	Specific type
Urinary tract infection	Symptomatic urinary tract infection
	Asymptomatic bacteriuria
	Other infections of the urinary tract
Surgical site infection	Superficial incisional primary/secondary
	Deep incisional
	Organ space infection (bone, cardiac, joint, etc.)
Bloodstream infection	Laboratory-confirmed bloodstream infection
	Clinical sepsis
Pneumonia	Clinically defined pneumonia
	Pneumonia with specific laboratory findings
	Pneumonia in immunocompromised patient
Bone and joint infection	Osteomyelitis
	Joint and bursa infection
Central nervous system	Intracranial infection
	Meningitis or ventriculitis
	Spinal abscess without meningitis
Cardiovascular system infection	Arterial or venous infection
	Endocarditis
	Myocarditis or pericarditis
	Mediastinitis
Eye, ear, nose, throat, or mouth infection	Conjunctivitis or other eye infection
	Ear mastoid
	Oral cavity
	Sinusitis
	Upper respiratory tract, laryngitis, epiglottitis
Gastrointestinal system	Gastroenteritis
	Hepatitis
	Intra-abdominal infection
	Necrotizing enterocolitis
Lower respiratory tract infection, other than pneumonia	Bronchitis, tracheobronchitis
Reproductive tract infection	Endometritis
	Other infections of the male or female reproductive tract
Skin and soft tissue infection	Skin infection
	Soft tissue infection
	Decubitus ulcer
	Omphalitis
Systemic infection	Disseminated infection

Source: Adapted from Horan et al.³

The CLABSI rate per 1,000 central line days is calculated by dividing the number of CLABSI by the number of central line days and multiplying the result by 1,000.⁸ Rates in pediatric intensive care units (PICUs) are estimated to vary from 1.0 to 4.7 per 1,000 central line days.^{11,12}

Diagnosis

Paired blood samples drawn from the catheter and a peripheral vein should be obtained for culture prior to initiation of antibiotic therapy. The same volume of blood should be inoculated into each bottle, and the bottles should be labeled

Table 3 Estimates of health care–associated infections occurring in acute care hospitals in the United States, 2011

Major site of infection	Percentage	Estimated number
Pneumonia	21.8%	157,500
Surgical site infections from any inpatient surgery	21.8%	157,500
Gastrointestinal illness	17.1%	123,100
Urinary tract infection	12.9%	93,300
Primary bloodstream infections	10.0%	71,900
Other types of infections	16.4%	118,500
Estimated total number of health care–associated infections in hospitals		721,800

Source: Adapted from Magill et al.²³

to reflect the sites from which the cultures were obtained. Cultures of blood samples obtained through catheters are associated with a higher rate of false positive results than cultures of peripheral blood samples.¹³ Thus, the specificity and positive predictive value for culturing blood samples from peripheral veins are higher than for culturing blood samples obtained through catheters.¹³ Both types of samples are associated with excellent negative predictive values. Positive cultures obtained through catheters should be presumed to reflect true infection for circumstances in which peripheral blood samples cannot be obtained and there is no clinical evidence for an alternative source of infection.

Definitive diagnosis of CLABSI in children is difficult. Insufficient blood samples may reduce the negative predictive values of the culture, and only blood samples obtained via the catheter may be available to guide management. It is critical that blood cultures include at least one sample drawn from a peripheral vein, although in young children obtaining peripheral blood cultures may be difficult or impossible. If feasible, at least two sets of blood cultures should be drawn from peripheral veins by separate venipuncture.

Treatment

In general, treatment of systemic intravenous catheter-related infection requires catheter management determination (e.g., salvage, exchange, or removal) and antibiotic therapy (e.g., selection of empiric therapy with subsequent tailoring to culture and sensitivity data).

In most cases, systemic antibiotic therapy is *not* required in the following circumstances: (1) positive catheter tip culture in the absence of clinical signs of infection; (2) positive blood cultures obtained through a catheter with negative cultures through a peripheral vein; and (3) phlebitis in the absence of infection.¹⁴

Following the diagnosis of catheter-related infection, catheter removal is warranted in the following circumstances: severe sepsis, hemodynamic instability, endocarditis or evidence of metastatic infection, and persistent bacteremia after 72 hours of antimicrobial therapy to which the organism is susceptible.¹³

Some pediatric providers favor attempting treatment of bacterial CLABSI without catheter removal due to greater difficulty with vascular access in children when compared

with adults. In such cases, both systemic and antimicrobial lock therapy may be warranted. The benefits of catheter removal must be weighed against the difficulty of obtaining alternative venous access. Several studies have reported successful CLABSI management among children without catheter removal; close monitoring is required, and the device should be removed in the event of clinical deterioration or recurrence of CLABSI.^{15,16}

The nature of the pathogen is also important for guiding decisions regarding catheter removal. Removal of long-term catheters can be a management challenge, particularly in the setting of surgically implantable intravascular devices. Therefore, it is important to establish true CLABSI.

Prevention

CLABSI can be prevented through proper management of the central line. These techniques are addressed in the CDC's Healthcare Infections Control Practices Advisory Committee Guidelines for the Prevention of Intravascular Catheter-Related Infections, 2011.¹⁰

In recent years, large-scale regional and statewide projects, such as the Pittsburgh Regional Healthcare Initiative and the Michigan Keystone Project, have demonstrated roughly 70% reductions in CLABSI rates in ICUs by increasing adherence to recommended best practices for the insertion of central lines.¹⁷ Decreases in CLABSIs have been attributed to various factors, including increased financial and leadership support for CLABSI prevention, improved education and engagement of clinicians in prevention efforts, packaging of prevention recommendations into practice bundles, increased data monitoring and feedback on progress, improvement of the safety culture in health care, and local and statewide collaborative prevention efforts.

The CDC and Healthcare Infection Control Practices Advisory Committee (HICPAC) have developed guidelines for the use of intravascular catheters.^{18–21} These guidelines have been developed for health care personnel who insert intravascular catheters and for persons responsible for surveillance and control of infections in hospital, outpatient, and home health care settings (–Table 1). These guidelines are intended to provide evidence-based recommendations for preventing intravascular catheter-related infections. Major areas of emphasis include (1) educating and training health

care personnel who insert and maintain catheters, (2) using maximal sterile barrier precautions during central venous catheter insertion, (3) using a >0.5% chlorhexidine skin preparation with alcohol for 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.

These guidelines also emphasize performance improvement by implementing bundled strategies, and documenting and reporting rates of compliance with all components of the bundle as benchmarks for quality assurance and performance improvement.¹⁰ In addition, the use of an electronic medical record–enhanced CLABSI prevention checklist coupled with a unit-wide real-time display of adherence was associated with increased compliance with evidence-based catheter care and sustained decrease in CLABSI rates.²²

Ventilator-Associated Pneumonia

Introduction

Pneumonia is the most common HAI, along with SSIs, both of which were estimated to account for 24% of all HAIs in 2011.²³ Intubation and mechanical ventilation increase the likelihood of pneumonia 6- to 21-fold.²⁴ Pneumonia that is not present at the time of hospital admission but occurs after 48 hours of intubation is generally classified as VAP. VAP occurs in 5% of mechanically ventilated children and is associated with a 20% mortality rate.²⁵ NHSN facilities reported incidence of VAP from 0 to 4.4 per 1,000 ventilator days.^{12,26}

Definition

The pathogenesis of VAP begins with the insertion of the endotracheal tube, which introduces bacteria into the airway.²⁴ There has been a trend to expand the definition to ventilator-associated events to encompass a broader range of conditions and complications that occur in mechanically ventilated patients. Current 2011 neonatal and pediatric diagnostic criteria are complex and subjective as no gold standard confirmatory test exists.²⁷ In September 2012, the CDC appointed a group of experts and stakeholders from across the nation to a Neonatal and Pediatric Ventilator-Associated Event Working Group to develop ventilator-associated event surveillance definitions for mechanically ventilated neonates and children as accomplished in January 2013 for the adult population. The June 2011 surveillance definitions are in effect for neonatal and pediatric patients until revised pediatric surveillance is defined by this working group.

Diagnosis

A diagnosis of pneumonia alone does not meet the criteria for a reportable VAP.²⁷ There are three levels of analysis: radiograph, signs and symptoms, and laboratory. The first inclusion criterion is analysis of serial chest radiographs with evidence of a new or progressive and persistent infiltrate, consolidation, cavitation, or pneumatocele(s) that occurs >48 hours after intubation. The next levels assess specific details

of the signs and symptoms of pneumonia, including worsening gas exchange, temperature, work of breathing, adventitious breath sounds, heart rate instability, leukopenia/leukocytosis, and sputum analysis.²⁷

Treatment

Pneumonia treatment in general revolves around supportive care and antibiotic coverage. Pharmacologic treatment of suspected pneumonia involves empiric antibiotic coverage with considerations of local bacteriologic patterns and refinement of coverage once culture and sensitivity results are known. Supportive ventilator management is dictated by the severity of disease.

Prevention

As with all HAIs, prevention is the key to minimizing the incidence of VAP. Daily discussion of the need for continued intubation as well as ongoing assessment of sedation to optimize the opportunity for extubation is crucial for prevention.¹ Research has demonstrated that dental plaque harbors bacteria; therefore, the goal of oral care is to remove dental plaque and bacteria.²⁸ Elevation of the head of bed to 30 to 45 degrees has been demonstrated to reduce the risk of pulmonary aspiration.²⁹ Together, these bundle items are integral to the prevention of VAP.

Surgical Site Infection

Introduction

The CDC has developed criteria that define SSI as infection related to an operative procedure that occurs at or near the surgical incision within 30 days of the procedure, or within 90 days if prosthetic material is implanted at surgery.³⁰ SSIs are often localized to the incision site but can also extend into deeper adjacent structures.

SSIs are one of the most common nosocomial infections, accounting for 22% of all HAIs in acute care hospitals as estimated by Magill et al²³ in 2011. However, the overall risk of SSI is low when considering the millions of patients who undergo surgical procedures each year.

Definition

Deep Incisional Surgical Site Infection

Deep incisional SSI must meet the following criterion: (1) infection occurs within 30 or 90 days after the NHSN operative procedure (where day 1 = the procedure date); (2) it involves deep soft tissues of the incision (e.g., fascial and muscle layers); and (3) patient has at least one of the following: (a) purulent drainage from the deep incision; (b) a deep incision that spontaneously dehisces or is deliberately opened by a surgeon, physician, or other designee and is culture-positive or not cultured, and patient has at least one of the following signs or symptoms: fever (>38°C), localized pain, or tenderness—a culture-negative finding does not meet this criterion; (c) an abscess or other evidence of infection involving the deep incision that is detected on direct examination, during invasive procedure, or by histopathologic examination or imaging test.⁴

Superficial Incisional Surgical Site Infection

A superficial incisional SSI must meet the following criterion: (1) infections occurs within 30 days after the operative procedure; (2) it involves only skin and subcutaneous tissue of the incision; and (3) patient has at least one of the following: (a) purulent drainage from the superficial incision; (b) organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision; (c) at least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat; or (d) diagnosis of superficial incisional SSI by the physician or designee.

Diagnosis

Development of an SSI is dependent upon a complex interaction between numerous factors, including the nature and number of organisms contaminating the surgical site, the health of the patient, and the skill and technique of the surgeon. Patient-related risk factors for SSI include diabetes, obesity, cigarette smoking, immunosuppression, malnutrition, colonization with microorganisms, presence of infection at a nonsurgical site, duration of preoperative hospitalization, and the severity of underlying illness(es).

Prevention

The predominant organisms causing SSIs after clean procedures are skin flora, including streptococcal species, *S aureus*, and coagulase-negative Staphylococci. The goal of antimicrobial prophylaxis is to prevent SSI by reducing the burden of microorganisms at the surgical site during the operative procedure.

Antimicrobial selection for SSI prophylaxis is based on cost, safety, pharmacokinetic profile, and bactericidal activity. Cefazolin is a drug of choice for many procedures; it has a desirable duration of action, spectrum of activity against organisms commonly encountered in surgery, reasonable safety, and low cost.

The most important factors for prevention of SSI are timely administration of effective preoperative antibiotics and careful attention to other perioperative control measures. Infection control measures are essential: hand hygiene and use of gloves and other barrier devices (e.g., masks, caps, gowns, drapes, and shoe covers) by operating room personnel. Application of antiseptics to the skin (e.g., chlorhexidine) is warranted to reduce the burden of skin flora. Preoperative hair removal has been associated with an increased risk for SSIs compared with no hair removal.²³

Surveillance of SSI with feedback of appropriate data to the health care team has been shown to be an important strategy in reducing the risk of SSIs. A successful surveillance program includes the use of epidemiologically sound infection definitions and effective surveillance methods, stratification of SSI rates according to risk factors associated with SSI development, and data feedback. A new CDC and HICPAC guideline for the prevention of SSI is scheduled for publication in 2014, and will replace the previous Guideline for Prevention of SSI, 1999.³¹

Catheter-Associated Urinary Tract Infection

Introduction

In 2014, Magill et al²³ reported that CAUTI accounted for ~13% of all acute care hospital–acquired infections in 2011. It has been estimated that 70 to 80% of these infections are caused by instrumentation of the urinary tract.³² CAUTI rates for facilities reporting to the NHSN in 2011 were 0 to 1.6 per 1,000 catheter days for pediatric patients, which is relatively low compared with 0.2 to 4.8 per 1,000 catheter days for adult patients.³² Interestingly, the reported rates in 2011 from ICUs that reported to NHSN were higher. They ranged from 1.4 to 3.1 per 1,000 catheter days in PICUs and 1.2 to 4.5 per 1,000 catheter days in adult ICUs.³³

Definition

A hospital-acquired CAUTI is defined as a UTI that occurs after an indwelling urinary catheter is or has been in place for >2 calendar days in a patient who is symptomatic or asymptomatic with positive dipstick or culture results.³⁴

Diagnosis

As with the other reportable HAIs, the CDC outlines criteria specific to the timing of urinary catheter placement in relation to the infection. In addition, the CDC diagnostic criteria outline age-specific signs and symptoms compatible with CAUTI. The most common presentation is fever with a positive urine culture result. Overall, infection in patients who have or have had an indwelling catheter in place for >48 hours with or without signs and symptoms of a UTI but with positive culture results of $\geq 10^3$ to 10^5 colony-forming unit/mL with no more than two species of microorganisms or a positive dipstick may be classified as a CAUTI.³⁴

Treatment

Ideally, once a CAUTI has been identified, the indwelling catheter is removed. Indwelling catheters may become coated with a biofilm, which consists of adherent microorganisms, the extracellular products, and host components, which conveys a survival advantage to the microorganisms.³⁵ For patients that have a clinical indication for an indwelling catheter and a CAUTI diagnosis, a new catheter should be placed and the closed drainage system should be replaced. A urine culture should be obtained from the freshly placed catheter prior to initiation of antimicrobial therapy to best guide treatment.³⁶ If the catheter can be discontinued, a culture of a voided midstream urine specimen should be obtained prior to initiation of antimicrobial therapy.³⁶ Pharmacologic treatment includes early empiric antibiotic therapy until culture and sensitivities are available to tailor antibiotic selection. The length of antibiotic therapy is commonly from 7 to 14 days depending upon the patient's response to therapy.³⁶

Prevention

Avoidance of unnecessary urinary catheter placement and minimizing the duration of catheterization is the primary strategy to preventing CAUTI.^{32,37} Interventions to prompt

staff to remove urinary catheters reduced the rate of CAUTI by 53%.³⁸ Much of the evidence for the CDC's recommendations for catheter maintenance as outlined in ►Table 1 is category 1B, which is a strong recommendation supported by low-quality evidence.³⁷

Summary

Since 2009, when the U.S. Department of Health and Human Services developed a national HAI action plan, there has been a decrease in the rate of reported infections. In a recent cohort study of neonatal ICUs and PICUs that reported data from 2007 to 2012 to NHSN, Patrick et al found that CLABSI decreased in the PICUs from 4.7 to 1.0 per 1,000 central-line days.¹² This decrease in CLABSI rate was estimated to result in a savings of ~\$70 million to the PICUs in participating hospitals during the study period.¹² VAP rates decreased in this cohort of PICUs from 1.9 to 0.7 per 1,000 ventilator-days.¹² Surveillance criteria for VAP have been subjective and nonspecific.³⁹ Reported VAP rates have decreased, yet to what extent these figures reflect actual improvements rather than artifacts of surveillance have made benchmarking for this HAI challenging.³⁹ CAUTI rates did not change significantly in PICUs, which was partially attributed to a change in CAUTI surveillance definition during the study period.¹² Although rates have improved, HAIs are often preventable and still remain a threat to patient safety.

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