Editorial

Pediatric Nosocomial Infections: Children Are Not Little Adults

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This issue *of Infection Control and Hospital Epidemiology* contains articles that highlight pediatric nosocomial infections. Current strategies for surveillance, prevention, and control of nosocomial infections have focused on general hospital services that primarily address the needs of adult patient populations. Although some of these strategies apply to infants and children, it is clear that pediatric patients and pediatric units are unique and require child-specific prevention and control plans. The following areas are critical for development of appropriate intervention strategies and will be the focus of this discussion: (1) surveillance methods appropriate to identify and analyze nosocomial infection rates in pediatric facilities; (2) guideline development based on reservoirs of infection, host-pathogen interactions, and modes of transmission in the pediatric patient population; (3) prevalence of resistant organisms and the use of antimicrobials in pediatric acute- and non-acute-care settings.

The concept that pediatric nosocomial infections differ from those in adults has been well established. In the early 1980s, the National Nosocomial Infection Surveillance (NNIS) System[1] reported that pediatric services had lower rates of infection than other hospital services; however, Ford-Jones and others in the late 1980s found a substantially higher nosocomial infection rate in children (6-7 infections/100 patients) than adults (4/100 patients) when viral infections and sites such as gastrointestinal and upper respiratory infections were included.[2] Although children have fewer wound infections, nosocomial pneumonias (ventilator-associated), and urinary tract infections than adults, they have more viral respiratory and viral gastrointestinal infections, bacteremias, and cutaneous infections.[3]

Multiple factors contribute to the differences in nosocomial infections of infants and young children and nosocomial infections of adults, including host factors, sources of infection, routes of transmission, and distribution of pathogens.[4] Host factors of particular importance that put young children at risk for nosocomial infection are immaturity of the immune system (especially in newborns and premature infants) and congenital anomalies. Premature infants are at high risk, as they have the most immature immune systems and require prolonged hospitalizations and invasive procedures. The rates of nosocomial infections in neonatal intensive-care units (NICUs) have been reported to be as high as 7% to 25%.[2,5] Children with congenital anomalies have a high risk of infection, not only from immune deficiencies related to specific syndromes (eg, Wiskott-Aldrich) but also because of loss of protective host factors such as anatomic barriers to infection (eg, cleft palate and meningomyelocele) . These children require multiple hospitalizations, increased numbers of devices, multiple surgeries, and prolonged lengths of stay.[6] In addition to sources of nosocomial infections common to all patients (invasive monitors, medical devices, other patients, and hospital personnel), the infant and young child are exposed to specific sources of infection including maternal infections; contaminated breast milk and infant formula; visitors to the hospital, including siblings; and contaminated fomites, such as toys shared with other patients on the units.

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The types of interactions among patients, healthcare workers, and the environment on a pediatric unit affect the transmission of infection. Patient-to-patient interactions are more frequent on a pediatric unit, where children are in close proximity and spend time in common areas, such as playrooms, where sharing of contaminated toys, equipment, and secretions can occur. In addition, healthcare workers on pediatric units have close contact with secretions of children, as routine care involves holding, cuddling, changing diapers, feeding, and wiping nasal discharge and drool. Healthcare workers can be exposed to infection and transmit it to other children on the unit as intermediary hosts, which has been demonstrated in respiratory syncytial virus (RSV) and pertussis outbreaks.[7,8] Nosocomial pathogens differ in children, and the diseases they cause may have different manifestations and greater impact on a pediatric unit than on an adult unit. Viruses cause 14% to 22% of all nosocomial infections in pediatric patients.[2,3] Viruses primarily are implicated in gastrointestinal (rotavirus) and respiratory infections (RSV, parainfluenza) and reflect the occurrence of these agents in the community. In contrast, nosocomial viral infections in adults primarily are endogenous (herpes simplex virus, cytomegalovirus). Infections such as varicella, measles, RSV, and pertussis can cause significant morbidity and major infection control problems on an infant-toddler unit due to susceptibility and ease of transmission, but require only minor intervention on an adult ward.

Surveillance is an essential component of any hospital infection control program. The collection, analysis, and dissemination of surveillance data has been shown to be the most important factor in the prevention of nosocomial infections.[9] The NNIS project has developed standardized methods of surveillance[10] and provides hospitals with comparative nosocomial infection data that at least partially adjust for intrinsic and extrinsic risks for infection. Although the NNIS System does address nosocomial infections in the NICU and pediatric intensive-care units (PICU),[11,12] the data have not been sufficient to address the unique aspects of pediatric nosocomial infections, such as risk of central line infections in the pediatric population outside of intensive-care units and the incidence of viral respiratory and gastrointestinal infections on pediatric services. The article by McLaws and colleagues[13] in this issue describes a surveillance technique that establishes a potential exposure risk ratio to allow hospitals to determine the peak time of risk for nosocomial RSV and thus to implement prevention and control strategies, optimize use of isolation facilities, and provide feedback on the outcome of infection control interventions.

There is debate among pediatricians regarding the definitions of infections used by the NNIS System as they pertain to pediatric populations, such as the criteria for sepsis in the NICU and nosocomial pneumonia in the PICU. For this information to be useful for intra- and interhospital comparisons, a more uniform child-specific surveillance system needs to be developed. A risk stratification of severity of illness for infants and young children needs to be developed further to make nosocomial infection rates comparable between hospitals. The NNIS System stratifies for birth weight and device use for calculating rates of infection in the NICU, but further stratification by scoring systems such as Acute Physiology, Age, and Chronic Health Evaluation,[14] Pediatric Risk of Mortality,[~~] or Score for Neonatal Acute Physiology[16] will be necessary, given that patient mixes in various NICUs and PICUs, etc, can differ significantly.

Infection control guidelines and recommendations have been published to assist hospitals and healthcare providers in the prevention and control of nosocomial infections. Most guidelines are developed for specific sites of infection or for control of specific pathogens such as bloodstream infections, urinary tract infections, nosocomial pneumonia, tuberculosis, and vancomycin-resistant *Enterococcus.* These guidelines are evidence-based, utilizing data regarding known reservoirs of infection, host-pathogen interactions, and modes of transmission. They are based on experience with hospital-acquired infections in adults, and, although they address some pediatric issues, they are developed for general hospital use. For example, recommendations have been made for adults to change intravascular catheters on a regular basis to decrease the amount of colonization of the catheter and reduce the risk of infection.[17] Obtaining vascular access in young children is difficult, and routine changing of some intravascular catheters is not feasible.

There has been considerable debate as to the type of empiric isolation recommended for infants and young children with respiratory infections of unknown etiology, particularly bronchiolitis and croup.[18] Some centers use contact precautions, as recommended, but others feel that viral infections such as influenza and adenovirus must be considered and add droplet precautions until a specific pathogen is identified. Tuberculosis control also has engendered much controversy, especially in pediatric facilities where young children with pulmonary TB swallow their secretions and do not cough and therefore are unlikely to transmit infection, yet current guidelines

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recommend isolation.[18] However, adult contacts of the child with TB are likely to be the source of infection and commonly are unrecognized as being potentially infectious while visiting the child on the pediatric unit, putting other patients and staff at risk.[19,20] The articles in this issue by Diekema and colleagues,[21] Hou and colleagues,[22] and Lhopital and colleagues[23] describe and evaluate molecular epidemiological tools that can be used further to elucidate reservoirs of infection and modes of transmission unique to the pediatric population, so that evidence-based, child-specific guidelines can be developed to prevent and control pediatric nosocomial infections.

One of the major challenges in the field of hospital epidemiology is the dramatic increase in antimicrobial resistance. The incidence of methicillin-resistant *Staphylococcus aureus* has increased steadily in pediatric facilities, and this organism has become endemic in some institutions.[24] This organism has been difficult to control, and successful eradication is infrequent. The dramatic rise in the number of vancomycin-resistant enterococcal (VRE) isolates in the early 1990s, as evidenced by the number of resistant isolates reported to the NNIS System, has contributed to the growing concern about the ability to control the spread of resistant organisms.[25] Although this problem primarily has affected the adult population, VRE have caused infections in pediatric patients.[26] Recent case reports of vancomycin-intermediate *S aureus* are very alarming and heighten the need for child-specific infection control strategies. Multidrug-resistant gram-negative bacilli such as *Klebsiella pneumoniae, Escherichia coli* and *Pseudomonas aeruginosa* have become widespread as well. Penicillin-resistant pneumococci have been reported widely in pediatrics and have become an important cause of community-acquired infections such as acute otitis media, pneumonia, and meningitis.[28] Hospital surveillance may play an important role in further elucidating the epidemiology of this organism. Antimicrobial use has been implicated as a risk factor for colonization and infection with resistant organisms. Antimicrobial prescribing patterns are different for pediatric patients than adults, based on the different types of infections and pathogens to which they are susceptible. There is only limited information regarding the use of antimicrobial agents, prevalence of resistant pathogens, risk factors for colonization, or infection with these organisms in the pediatric population. Logsdon and colleagues[29] report in this issue a study that evaluates the use of vancomycin in a pediatric teaching hospital, in which they found that vancomycin use (based on published guidelines) was inappropriate in 54% of the patients and the effect of an educational intervention program was only transitory. They had to modify the criteria for use to meet the needs of a pediatric facility. This highlights the need to evaluate the use of antimicrobials in the pediatric setting, in addition to establishing specific methods of surveillance of resistant organisms in pediatric populations, in order to develop child-specific interventions to reduce the emergence and prevent the transmission of these pathogens.

Although the hospital is the traditional setting for surveillance, there may be other reservoirs of infection that contribute to the spread of resistant organisms. Nursing homes are an important source for adult inpatient units of resistant organisms[30] such as methicillin-resistant S *aureus* and aminoglycoside-resistant gram-negative bacilli, as colonized and infected patients travel back and forth between facilities. Child-care centers in Kentucky have been found to have a high level of penicillin-resistant pneumococci[31] and may serve as a reservoir of infection for the community. Some pediatric facilities routinely are doing surveillance cultures on all transfers from other healthcare facilities and initiating isolation precautions until culture results are available, in order to prevent the spread of unrecognized resistant pathogens. The roles of pediatric facilities such as day-care centers, long-term-care facilities, and rehabilitation hospitals in the spread of these pathogens need to be established in order to develop effective strategies for the control of antimicrobial resistance in pediatric patients.

Where do we go from here in the prevention and control of pediatric nosocomial infections? The following must be addressed in order to develop child-specific strategies for the prevention and control of pediatric nosocomial infections:

1. Surveillance methods using risk stratification for severity of illness need to be developed in order to get baseline data of nosocomial infections in intensive-care and nonintensive-care pediatric settings, as well as non-acute-care institutions, such as long-term-care facilities, medical day-care centers, and pediatric rehabilitation hospitals, to establish benchmark rates that will permit accurate and reliable intrahospital and interhospital comparisons.

2. Site-specitic risk factors for infections such as device-related bloodstream infections and ventilator-associated pneumonia in children need to be identified.

3. Type and incidence of resistant organisms in various pediatric settings (such as acute-care and non-acute-care settings) and in special populations where long-term prophylaxis or frequent courses of antibiotics are used (such as sickle cell, human

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immunodeficiency virus, and cystic fibrosis patients) should be established. Evaluation of antimicrobial prescribing practices will allow development of interventions to control inappropriate use in children.

Nosocomial infections pose a significant threat to the hospitalized child and will continue to be a cause of significant morbidity, mortality, and long-term sequelae. Although more children will be treated as outpatients and be discharged earlier to non-acute-care facilities in the future, hospitalized children will be sicker, requiring more invasive therapies and treatments, putting them at increased risk for hospital-acquired infections. Nosocomial infections will occur more frequently in non-acute-care facilities, and infections acquired in the home are being identified in home-care patients. We have come far in recognizing and addressing the unique aspects of pediatric nosocomial infections; however, further research needs to be done to address these important issues.

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