

# Infection Control in Pediatrics

Jurai Wongsawat, M.D.

## ABSTRACT

Infection control in Pediatric settings has become increasingly concerned with the impact of evolving sophisticated treatments and the emergence and re-emergence of various infectious diseases. Because of their dependency and immunological naivety, children are more prone than adults to contract infectious diseases and to exhibit prolonged transmission. This leads to some unique characteristics when considering the control of pediatric infections. Healthcare-associated infections (HAIs) in pediatrics can be divided into 2 groups including 1) transmission occurring from hospitalized index cases who previously acquired infection from the community (e.g., rotavirus, pertussis, and influenza) and 2) transmission truly originating in healthcare settings (e.g. device associated infections in intensive care units). Other factors influencing HAIs are the use of breastmilk, toys, type of caring, and the environment. Generally, the incidence of HAIs in children differs from that observed in adults. Viruses are the main pathogens in general pediatric units. However, bacteria are the main causes of device-associated infections, including catheter-related blood stream infections, and ventilator-associated pneumonia in neonatal and pediatric intensive care units. An increased trend of infections with multidrug-resistant bacteria has been observed in some units. Basic infection control policies including standard precautions, transmission-based precautions, isolation precautions, hand hygiene, respiratory and cough etiquette, and antibiotic control programmes are the fundamentals in pediatric infection control. Not all site-specific infection control measures recommended in adult populations apply to pediatric populations because of differences in host characteristics and the limited number of research studies in children. Pediatric units should establish their own policies and should ensure of adherence based on the ongoing researches. (*J Infect Dis Antimicrob Agents* 2008;25:153-64.)

## INTRODUCTION

Healthcare-associated infections (HAIs), previously called nosocomial infections, are now defined as any infection that is not incubating or present at the time of hospitalization, and that develops

48 hours or more after hospitalization or within 10 days of hospital discharge.<sup>1</sup> Infection control in pediatrics needs unique considerations as there are several factors differing from adult populations and findings in adults may not be relevant to pediatric populations. These

---

Pediatric Unit, Bamrasnaradura Infectious Diseases Institute, Ministry of Public Health (MOPH), Tiwanon Road, Nonthaburi 11000, Thailand.

Received for publication: November 12, 2008.

Reprint request: Jurai Wongsawat, M.D., Pediatric Unit, Bamrasnaradura Infectious Diseases Institute, Ministry of Public Health (MOPH), Tiwanon Road, Nonthaburi 11000, Thailand.

E-mail: juraiw@hotmail.com

**Keywords:** Infection control measures, Pediatrics, Epidemiology, Associated factors

factors include host conditions, pathogens, types of exposure, and environmental factors. In pediatric populations, there are correlations between outbreaks in communities and in hospitals, especially for viral infections. Therefore, infection control in pediatrics needs emphasis both in healthcare and non-healthcare settings (e.g. schools, nurseries, and foster homes). This review focuses on the healthcare setting.

### Epidemiology

The reported incidence of nosocomial infections in Pediatric age groups in develop countries varies from 2-13 percent.<sup>2-5</sup> The incidence in neonates ranges from 6-8.9 per 1,000 patient-days.<sup>6</sup> The highest incidences occur in intensive care units (pediatric and neonatal), oncology units, patients receiving total parenteral nutrition (TPN), those with prolonged hospitalization and receiving medical-in-line devices, or those who have underlying diseases. These findings are similar to adult populations. However, in pediatrics, the distribution of infected sites and pathogens differs from adults and also varies among age groups. Limited laboratory capacity to establish diagnoses especially for viral transmissible diseases and technical difficulties in collecting specimens from children pose problems in establishing causative diagnosis in pediatric populations and lead to under-diagnosis of HAIs.

According to the available data, mostly from developed countries, the characteristics of HAIs in pediatric populations vary among types and levels of healthcare settings. A European study group revealed that the overall incidence of HAIs was 2.5 percent, varying from 1 percent in general pediatric units to 23.6 percent in pediatric intensive care units (PICUs).<sup>7</sup> The proportion of lower respiratory tract infections was found to be 13 percent in general pediatric units and 53 percent in PICUs. Seventy-six percent of HAIs in general pediatric units were found to be gastrointestinal

infections, most commonly viral. Bloodstream infections were the most important HAI in neonatal units (71%) and 66 percent of cases were associated with the central venous catheters. Urinary tract infections accounted for 11 percent of HAIs. The overall causative pathogens were bacterial (68%; Gram-negative bacilli 37%, Gram-positive cocci 31%), *Candida* (9%), and viruses (22%). The prevalence of antimicrobial depended on the location, with the highest rates being observed in PICUs, where 26.3 percent of *Staphylococcus aureus* and 89 percent of coagulase-negative staphylococci (CoNS) were found to have methicillin-resistance. Extended-spectrum beta-lactamase-producing strains were also found in 37.5 percent of *Klebsiella pneumoniae*. The mortality due to HAIs in PICUs and neonatal units was 10 percent and 17 percent, respectively.

Focusing on PICU settings, the data in 1999 from the National Nosocomial Infections Surveillance system of the Centers for Disease Control and Preventions (NNIS)<sup>8</sup> revealed that the most frequently infection sites were primary bloodstream infections (28%), pneumonia (21%), and urinary tract infections (15%), and were almost always related to the use of invasive devices. The most common bloodstream isolates were CoNS (38%) and aerobic Gram-negative bacilli (25%). The most common pathogen causing pneumonia was *Pseudomonas aeruginosa* (22%), whereas *Escherichia coli* was the most common pathogen (19%) causing for urinary tract infections. An increasing trend of *Enterobacter* species was observed in this study. There was no correlation observed between device-associated infection rates and length of hospital stay, number of hospital beds, or season.

In NICU settings, pneumonia is the most frequently infection, followed by catheter-associated urinary tract infection (CA-UTI) and TPN-associated

blood stream infection as seen in a study from Taiwan published in 2007.<sup>9</sup>

There are limited data available from developing countries. However, it has been reported that healthcare-associated neonatal infections in developing countries are 3-20 times higher than those reported in industrialized countries.<sup>10</sup> *K. pneumoniae*, and other Gram-negative bacilli and *S. aureus* have been the major pathogens identified among bloodstream isolates. The predominate pathogens in some particular groups (e.g. neonates) are also different between developing and developed countries.

### General associated factors

#### Host or intrinsic factors

Because of their immature immune system and a lack of previous exposure to infections, children are prone to contract previously unexposed/unimmunized infections. Other conditions including congenital anomalies and congenital or acquired immunodeficiency make these particular groups vulnerable to infection. Because of the immaturity of their immune system, the first exposure to some pathogens (e.g., rotavirus and *Bordetella pertussis*) can lead to severe disease and prolonged shedding of organism in clinical specimens. Furthermore, the uncontrolled dispersal of fluids and secretions in routine daily activities enhances opportunities for infections to spread. Several studies have revealed the high prevalences of HAI in neonates. All components of the immune system are deficient in neonates and the degree of deficiency is inversely proportional to the gestational age. Infants in neonatal intensive care units appear to have highest HAI rates.<sup>11-12</sup> The incidence has also shown to be greatest among those with preterm weights < 1,000 g.<sup>9</sup>

As their dependency to caretaker, type of caring including feeding, playing, changing soiled diapers, and

cleaning respiratory secretions also play role in pathogens transmission.

### Pathogen factors

#### Seasonal epidemics

Children are prone to contract many viral infections which have their highest incidences in winter especially respiratory viruses [Respiratory Syncytial virus (RSV), Influenza and Parainfluenza Viruses], and gastrointestinal viruses (e.g. Rotavirus). This can lead to parallel epidemics in both the community and in hospitals when children need to be hospitalized.

#### Characteristics of pathogens and routes of transmission

The main routes of transmission are direct and indirect contact, droplets and airborne spread. Most infectious agents are transmitted by the hands of healthcare personnel. Droplet transmission requires the exposure of mucous membranes to large respiratory droplets (particle size > 5 µm) within 1 to 2 meters of the infected person, who may be coughing or sneezing. Infections that require droplet precautions include those that caused by adenovirus, *Coccynebacterium diphtheriae*, *Haemophilus influenzae* type b (invasive), Influenza Virus, Mumps Virus, *Mycoplasma pneumoniae*, *Neisseria meningitidis* (invasive), Parvovirus B19, *Bordetella pertussis*, Plague (Pneumonic), Rubella virus, SARS Virus, and *Streptococcus*, *Pyogenes* (pharyngitis, pneumonia, and scarlet fever).<sup>13</sup> Infections that require contact precaution include those that caused by multidrug-resistant bacteria (vancomycin-resistant enterococci, methicillin-resistant *S. aureus*, multidrug-resistant Gram-negative bacilli), *Clostridium difficile*, *C. diphtheriae* (cutaneous), Enterovirus, *E. coli* O157:H7, other shiga toxin-producing *E. coli*, Hepatitis A Virus, Herpes simplex, Varicella-zoster virus, bacteria (impetigo, major abscess, and cellulitis

Virus), Parainfluenza Virus, RSV, Rotavirus, scabies, *Shigella*, *S. aureus* (wounds), and viruses of hemorrhagic fever group.<sup>13</sup> Aerosol transmission can be divided into 1) obligate transmission (occurring through small particles) e.g. tuberculosis, 2) preferential transmission (occurring through multiple routes but small particle aerosols are the predominant route) e.g. measles and shingles, and 3) opportunistic transmission (occurring through other routes, but under certain environments; these could be transmitted by fine particular aerosols) e.g., smallpox, severe acute respiratory syndrome caused by SARS virus, and influenza.<sup>14</sup> Many pathogens can also be transmitted by more than one route. The route of transmission of emerging pathogens may not be apparent at first and empiric precautions should be placed first while information is gathered on the routes of transmission. Pediatric populations are generally regarded as less likely to transmit *Mycobacterium tuberculosis* although there has been one report of nosocomial tuberculosis transmission from a premature baby with congenital tuberculosis which resulted in 19 percent of healthcare workers converting to a positive tuberculin skin test.<sup>15</sup>

### Health care setting-associated factors

#### Environment

Children often share common playing areas and toys both in the community and in healthcare settings. Several reports have revealed toys as a possible way of fomite transmission. One study reported that 14 percent of hard toys and 90 percent of soft toys were contaminated with coliforms.<sup>16</sup> Bath toys have also shown to be associated with an outbreak of *P. aeruginosa* in a pediatric oncology ward.<sup>17</sup> Breast milk has also been found to be a source of bacterial infection via the processes of pumping, collection and storage.<sup>18</sup> Maternal education needs to be emphasized.

There have been concerns regarding contaminated infant formula with *Enterobacter sakazakii*.<sup>19</sup> Safe preparation, good storage practices and appropriate administration of infant formula need to be emphasized.

#### Ratio of staff to patients

Transmission is facilitated by overcrowding of patients and under-staffing and several reports have shown this situation is associated with increased HAIs in PICU, NICU, and general pediatric units.<sup>20-22</sup>

### Infection control Measures

Basic infection control measures in healthcare settings apply to both adult and child populations. These include standard precautions (Annex 1) and transmission-based precautions (Annex 2).<sup>13</sup> In general pediatric settings, we may be faced with 2 groups of patients including 1) patients who acquired infection from the community (e.g., rotavirus, pertussis, influenza) and 2) patients who truly acquired infection originating in healthcare settings (e.g., device-associated infections in ICUs). Regarding group 1, we aim for early containment of the disease, therefore empiric syndromic approaches (Annex 3) are recommended.<sup>13</sup> There has been report that a “bundle multi-component” program including 1) prompt laboratory confirmation, 2) cohort of patients and nursing staff and 3) use of contact precautions (gloves and gowns) was able to reduce RSV transmission.<sup>23</sup> The World Health Organization (WHO) recently also highlighted the importance of early containment of respiratory pathogens by publishing interim guidelines regarding infection prevention and the control of epidemic-and pandemic prone acute respiratory diseases in health care (Annex 4).<sup>24</sup> Regarding the transmission of Rotavirus, which is a very hardy virus, there are still controversies regarding the efficacy of the bundle approach.<sup>25</sup>

Regarding group 2, there are less data and clinical

**Annex 1. Recommendations for application of standard precautions for care of all patients in a healthcare settings (modified from reference 13).**

| Component   | Recommendations  |
|---|--|
| Hand hygiene  | <p>After touching blood, body fluids, secretions, excretions, or contaminated items; immediately after removing gloves; between patient contacts.</p> <p>Alcohol-containing antiseptic hand rubs preferred except when hands visibly are soiled with blood or other proteinaceous materials or if exposure to spores (e.g., <i>Clostridium difficile</i>, <i>Bacillus anthracis</i>) is likely to have occurred</p>      |
| Personal protective equipment (PPE)                   |  |
| Gloves  | For touching blood, body fluids, secretions, excretions, or contaminated items; for touching mucous membranes and non-intact skin  |
| Gown  | During procedures and patient-care activities when contact of clothing/exposed skin with blood/body fluid secretions and excretions is anticipated   |
| Mask, eye protection (goggles), face shield           | During procedures and patient-care activities likely to generate splashes or sprays of blood, body fluids, or secretions, especially suctioning and endotracheal intubation, to protect health care personnel. For patient protection, use of a mask by individual inserting an epidural anesthesia needle or performing myelograms when prolonged exposure of the puncture site is likely to occur.                     |
| Soiled patient-care equipment                         | Handle in a manner that prevents transfer of microorganisms to others and to environment; wear gloves if visibly contaminated; perform hand hygiene  |
| Environmental control                                 | Develop procedures for routine care, cleaning and disinfection of environmental surfaces, especially frequently touched surfaces in patient care areas   |
| Textiles (linens) and laundry                         | Handle in a manner that prevents transfer of microorganisms to others and the environment  |
| Injection practices (use of needles and other sharps) | Do not recap, band, break, or hand manipulate used needles; if recapping is required, use a one-handed scoop technique only; use needle-free safety devices when available; place used sharps in puncture-resistant container. Use a sterile, single-use, disposable needle and syringe for each injection given. Single-dose medication vials are preferred when medications are administered to more than one patient. |
| Patient resuscitation                                 | Use mouthpiece, resuscitation bag, other ventilation devices to prevent contact with mouth and oral secretion  |
| Patient placement                                     | Prioritize for a single-patient room if the patient is at increased risk of transmission; is likely to contaminate the environment; does not maintain appropriate hygiene or is at increased risk of acquiring infection or developing an adverse outcome following infection.   |
| Respiratory hygiene/cough etiquette                   | Instruct symptomatic people to cover their mouth/nose when sneezing/coughing; use tissues and dispose in no-touch receptacles; observe hand hygiene after soiling of hands with respiratory secretions; wear surgical mask if tolerated or maintain spatial separation (> 3 feet if possible)  |

**Annex 2. Transmission-based precautions for hospitalized patients (modified from reference 13).**

| Category of precautions | Single-patient room   | Respiratory tract/mucous membrane protection | Gowns | Gloves |
|-------------------------|---|--|-------|--------|
| Airborne                | Yes, with negative air-pressure ventilation, 6-12 air exchanges per hour, and HEPA filtration | Respiration: N95 or higher level             | No    | No     |
| Droplet                 | Yes   | Surgical masks                               | No    | No     |
| Contact                 | Yes   | No   | Yes   | Yes    |

HEPA: high efficiency particulate air

research in pediatric populations, compared with adult populations. Infection control measures recommended in adults cannot be totally adopted to practices in pediatric populations. However, some recommendations give insights into how to modify its use for pediatrics given the lack of specific research in pediatrics. Specific issues which need to be concerned in pediatrics include the following;

**Ventilator-associated pneumonia (VAP)**

VAP is a nosocomial infection occurring in patients receiving mechanical ventilatory support that is not present at the time of intubation and that develops more than 48 hours after the initiation of that support.<sup>26</sup> Ninety-five percent of nosocomial pneumonias occur in patients receiving mechanical ventilatory support.<sup>8</sup> *P. aeruginosa*, *Enterobacter cloacae*, *S. aureus*, and viruses are the most common pathogens.<sup>7,8</sup> Children in the 2-12-month age group have the highest age-specific rate. Most risk factors for the development of VAP in the pediatric population are similar to adults, although some risk factors are different including immunodeficiency, immunosuppression, and neuromuscular blockade.<sup>27</sup> TPN, steroids and H<sub>2</sub>-blockers are also associated with VAP.<sup>28</sup> The Institute of Healthcare Improvement (IHI) has established the bundles for prevention of VAP<sup>29</sup>; the bundle consists of 1) elevation of the head of the

patient's bed to 30-45 degrees, 2) a daily sedation and neuromuscular blockade holiday with an extubation readiness trial, 3) peptic ulcer disease prophylaxis, and 4) deep venous thrombosis prophylaxis. However, there are some modifications of the IHI Adult Ventilator Bundle for pediatrics<sup>29</sup> including 1) elevation of the head of the patient's bed to 15-30 and 30-45 degrees for neonates and infants 2) no recommendation of sedation vacation recommended in pediatrics due to high risk of unplanned extubation, 3) peptic ulcer disease prophylaxis being used as appropriate for age and condition of the child, and 4) deep vein thrombosis prophylaxis being used as appropriate for age and condition of the child. The drawback of H<sub>2</sub>-blockers relating to higher rates of VAP in adult populations (compared with the cytoprotective agent sucralfate) has not been studied well in pediatrics. A randomized, controlled trial has shown that ventilated infants positioned on their sides were less likely to have tracheal colonization which supports the idea that gravity probably could prevent VAP.<sup>30</sup>

**Bloodstream infection**

In developed countries, bloodstream infection is the most infection in PICU. The "central line bundle" recommended in adults consists of 1) hand hygiene, 2) maximal barrier precaution, 3) chlorhexidine skin antisepsis, (4) Optimal catheter site selection (the

**Annex 3. Clinical syndromes or conditions warranting precautions in addition to standard precautions to prevent transmission of epidemiologically important pathogens pending (modified from reference 13).**

| Clinical syndrome or condition   | Potential pathogens                                    | Empiric precautions  |
|--|--|--|
| Diarrhea   | Enteric pathogens                                      | Contact  |
| Acute diarrhea with a likely infectious cause  | <i>Clostridium difficile</i>                           | Contact; use only soap and water for handwashing   |
| Diarrhea in patient with a history of recent antimicrobial use   |  |  |
| Meningitis   | <i>Neisseria meningitidis</i><br>Enteroviruses         | Droplet<br>Contact   |
| Rash or exanthems, generalized, unknown Petechial or ecchymotic with fever                                     | <i>N. meningitidis</i> , <i>Haemophilus influenzae</i> | Droplet  |
| Vesicular  | Hemorrhagic fever viruses<br>Varicella-zoster virus    | Add contact plus face/eye protection<br>Airborne and contact   |
| Maculopapular with coryza and fever  | Measles virus  | Airborne   |
| Respiratory tract infections   | <i>Mycobacterium</i>                                   | Airborne   |
| Pulmonary cavity disease   |  |  |
| Paroxysmal or severe persistent cough  | <i>Bordetella pertussis</i>                            | Droplet  |
| During periods of pertussis activity in the community  |  |  |
| Viral infections, particularly bronchitis and croup, in infants and young children                             | Respiratory viral pathogens                            | Contact plus droplet until Adenovirus and Influenza virus are excluded   |
| Risk of multidrug-resistant microorganisms   |  |  |
| History of infection or colonization with multidrug-resistant organisms  | Resistant bacteria                                     | Contact  |
| Skin, wound, or urinary tract infection in a patient with a recent stay in a hospital or chronic care facility | Resistant bacteria                                     | Contact until resistant organism is ruled out by surveillance cultures   |
| Skin or wound infection  | <i>Staphylococcus aureus</i> ,                         | Contact  |
| Abscess or draining wound that cannot be covered   | Group A <i>Streptococcus</i>                           | Droplet precautions for the first 24 hours of appropriate antimicrobial therapy if invasive group A streptococcal disease is suspected |

**Annex 4. Infection control precautions for healthcare workers (HCWs) and caregivers providing care for patients with acute respiratory diseases (ARD) according to a sample of pathogens (modified from reference 24).**

| Precaution  | No pathogen identified<br>(e.g. influenza-like illness<br>without risk factor of<br>potential concern) | Pathogen                                 |  |                                       |  |  |   |
|---|--|--|--|---------------------------------------|--|--|---|
|   |  | Bacteria<br>ARD*                         | Parainfluenza<br>RSV, and<br>Adenovirus  | Adenovirus                            | New Influenza virus<br>with no sustained<br>human-to-human<br>transmission | SARS                                     | Novel<br>organisms                        |
| Hand hygiene  | Yes  | Yes                                      | Yes                                      | Yes                                   | Yes  | Yes                                      | Yes                                       |
| Gloves  | Risk assessment  | Yes                                      | Risk assessment                          | Yes                                   | Yes  | Yes                                      | Yes                                       |
| Gown  | Risk assessment  | Yes                                      | Risk assessment                          | Yes                                   | Yes  | Yes                                      | Yes                                       |
| Eye protection  | Risk assessment  | Risk assessment                          | Risk assessment                          | Yes                                   | Yes  | Yes                                      | Yes                                       |
| Medical mask on HCWs and caregivers                                 | Yes  | Yes                                      | Yes                                      | Yes                                   | Yes  | Yes                                      | Not routinely                             |
| Particulate<br>respirator on<br>HCWs and<br>caregivers              | No   | No                                       | No                                       | Not routinely                         | Not routinely  | Not routinely                            | Yes                                       |
|   | No   | No                                       | No                                       | Not routinely                         | Not routinely  | Not routinely                            | Yes                                       |
|   | Yes  | Not routinely                            | Yes                                      | Yes                                   | Yes  | Yes                                      | Yes                                       |
| Medical mask on patient when outside<br>isolation areas             | Yes  | Yes                                      | Yes                                      | Yes                                   | Yes  | Yes                                      | Yes                                       |
| Single room   | Yes, if available  | Yes, if available                        | Yes, if available                        | Yes                                   | Yes  | Yes                                      | Not routinely                             |
| Airborne precaution room  | No   | No                                       | No                                       | Not routinely                         | Not routinely  | Not routinely                            | Yes                                       |
| Summary of precautions (excluding<br>aerosol-generating procedures) | Standard plus droplet  | Standard<br>plus droplet<br>plus contact | Standard<br>plus droplet<br>plus contact | Standard plus droplet<br>plus contact | Standard<br>plus droplet<br>plus contact                                   | Standard<br>plus droplet<br>plus contact | Standard<br>plus airborne<br>plus contact |

\*bacterial ARD: *S. pneumoniae*, *H. influenzae*, *Chlamydial* spp., *M. pneumoniae*

RSV: respiratory syncytial virus, SARS: severe acute respiratory syndrome

subclavian vein is the preferred site for non-tunneled catheters in adults), and 5) daily review of line with prompt removal if unnecessary. No formal guidelines have been developed in children, however, there are some modifications which could be suggested, for example, no chlorhexidine recommended in patients of < 2 months of age.<sup>31</sup> A retrospective cohort study of children with catheter-associated bloodstream infections (BSIs) due to *Escherichia coli* and/or *Klebsiella* revealed risk factors for poor outcome (e.g. death or recurrence of infection) including receipt of mechanical ventilation and receipt of total parenteral nutrition. A significant proportion of children with catheter-associated BSI were treated successfully without catheter removal.<sup>32</sup>

The incidence of catheter-related BSI (CRBSI) in the 48 hours following peripherally inserted central catheter (PICC) removal was not different than the incidence of CRBSI when a PICC was in-dwelling.<sup>33</sup> There was no evidence from this study to support antibacterial prophylaxis before PICC removal.<sup>33</sup>

### **Catheter-associated urinary tract infection**

The need for fluid balance monitoring in particular pediatric patients (e.g. congenital heart disease) necessitates urinary catheter insertion. A duration of at least 3 days of catheterization has been reported to be a risk factor for urinary tract infection in children.<sup>34</sup> Therefore, preventive measures should encourage the removal of urinary catheters as soon as possible.

### **Surgical sites infections**

In general, infection control measures are similar to adults and some concerns are less problematic in children, e.g. hair removal. Pediatric populations differ mainly from adult populations in the type and dosing of

antibiotic prophylaxis.<sup>35</sup>

### **Multidrug-resistant organisms**

Measures to prevent multidrug-resistant organisms include 1) antibiotic control programmes and 2) strictly adhering to infection control programmes. The application of standard and contact precautions, screening of high-risk patients during outbreaks and reducing the use of third-generation cephalosporins and amino-glycosides have been shown to assist in containing multidrug-resistant *K. pneumoniae* (MRKP) epidemics in PICUs. Antibiotic cycling has not been consistently shown to reduce emergence of these organisms. Receipt of extended-spectrum cephalosporins in the previous 30 days has been found to be a risk factor for bloodstream infection caused by extended-spectrum beta-lactamase-producing *E. coli* or *Klebsiella* species.<sup>36</sup> Risks including age less than 12 weeks, previous treatment with third-generation cephalosporins and aminoglycosides were all found to be associated with MRKP colonization and/or infection.<sup>37</sup>

### **Neonates**

Bloodstream infection is the leading cause of HAI in this age group<sup>38</sup>, whereas the frequency of VAP varies according to birth weight.<sup>39</sup> The incidence of VAP increases in extremely preterm neonates and is associated with a high mortality.<sup>40</sup> Infection control measures to prevent the spread of resistant pathogens are similar to adults. A report has shown that an infection control intervention consisting mostly of nurse and physician education (in particular, hand hygiene) and improvements in vascular access care can have a sustained reduction on infection rates among neonates.<sup>41</sup> Multimodal strategies including hand hygiene have been shown to reduce BSI rates.<sup>42-43</sup> Routine gowning by attendants and visitors in nurseries has not been

shown to reduce the rate of bacterial colonization/infection rates in neonates.<sup>44</sup>

### CONCLUSION

Infection control in Pediatrics is a unique issue. Given several different aspects from adults, implementation of infection control guidelines from adult to pediatric populations need to be considered carefully and more studies are needed.

### References

1. Siegal JD, Grossman L. Pediatric infection prevention and control. In: Long SS, Pickering LK, Prober CG, eds. *Principle and Practice of Pediatric Infectious Diseases*. 3<sup>rd</sup> ed. Elsevier, 2008: 9-23.
2. Welliver RC, McLaughlin S. Unique epidemiology of nosocomial infection in a children's hospital. *Am J Dis Child* 1984;138:131-5.
3. Ford-Jones EL, Mindorff CM, Langley JM, et al. Epidemiologic study of 4,684 hospital-acquired infections in pediatric patients. *Pediatr Infect Dis J* 1989;8:668-75.
4. Jarvis WR, Robles B. Nosocomial infections in pediatric patients. *Adv Pediatr Infect Dis* 1996;12: 243-95.
5. Jarvis WR, Edwards JR, Culver DH, et al. Nosocomial infection rates in adult and pediatric intensive care units in the United States. National Nosocomial Infections Surveillance System. *Am J Med* 1991; 91:185S-91S.
6. Stover BH, Shulman ST, Bratcher DF, Brady MT, Levine GL, Jarvis WR. Nosocomial infection rates in US children's hospitals' neonatal and pediatric intensive care units. *Am J Infect Control* 2001;29: 152-7.
7. Raymond J, Aujard Y. Nosocomial infections in pediatric patients: a European, multicenter prospective study. European Study Group. *Infect Control Hosp Epidemiol* 2000;21:260-3.
8. Richards MJ, Edwards JR, Culver DH, Gaynes RP. Nosocomial infections in pediatric intensive care units in the United States. National Nosocomial Infections Surveillance System. *Pediatrics* 1999; 103:e39.
9. Su BH, Hsieh HY, Chiu HY, Lin HC, Lin HC. Nosocomial infection in a neonatal intensive care unit: a prospective study in Taiwan. *Am J Infect Control* 2007;35:190-5.
10. Zaidi AK, Huskins WC, Thaver D, Bhutta ZA, Abbas Z, Goldmann DA. Hospital-acquired neonatal infections in developing countries. *Lancet* 2005;365:1175-88.
11. Grohskopf LA, Sinkowitz-Cochran RL, Garrett DO, et al. A national point-prevalence survey of pediatric intensive care unit-acquired infections in the United States. *J Pediatr* 2002;140:432-8.
12. Sohn AH, Garrett DO, Sinkowitz-Cochran RL, et al. Prevalence of nosocomial infections in neonatal intensive care unit patients: Results from the first national point-prevalence survey. *J Pediatr* 2001; 139:821-7.
13. American Academy of Pediatrics. Infection control for hospitalized children. In: Pickering L, Baker C, Long S, McMillan J, eds. *Red Book 2006: Report of the Committee on Infectious Diseases*. 27<sup>th</sup> ed. Elk Grove Village, IL: American Academy of Pediatrics, 2006: 153-63.
14. Roy CJ, Milton DK. Airborne transmission of communicable infection--the elusive pathway. *N Engl J Med* 2004;350:1710-2.
15. Mouchet F, Hansen V, Van Herreweghe I, et al. Tuberculosis in healthcare workers caring for a congenitally infected infant. *Infect Control Hosp Epidemiol* 2004;25:1062-6.
16. Merriman E, Corwin P, Ikram R. Toys are a potential source of cross-infection in general practitioners'

- waiting rooms. *Br J Gen Pract* 2002;52:138-40.
17. BATTERY JP, ALABASTER SJ, HEINE RG, et al. Multiresistant *Pseudomonas aeruginosa* outbreak in a pediatric oncology ward related to bath toys. *Pediatr Infect Dis J* 1998;17:509-13.
  18. OLVER WJ, BOND DW, BOSWELL TC, WATKIN SL. Neonatal group B streptococcal disease associated with infected breast milk. *Arch Dis Child Fetal Neonatal Ed* 2000;83:F48-F49.
  19. DRUDY D, MULLANE NR, QUINN T, WALL PG, FANNING S. *Enterobacter sakazakii*: an emerging pathogen in powdered infant formula. *Clin Infect Dis* 2006;42:996-1002.
  20. JACKSON M, CHIARELLO LA, GAYNES RP, GERBERDING JL. Nurse staffing and health care-associated infections: Proceedings from a working group meeting. *Am J Infect Control* 2002;30:199-206.
  21. ARCHIBALD LK, MANNING ML, BELL LM, BANERJEE S, JARVIS WR. Patient density, nurse-to-patient ratio and nosocomial infection risk in a pediatric cardiac intensive care unit. *Pediatr Infect Dis J* 1997;16:1045-8.
  22. STEGENGA J, BELL E, MATLOW A. The role of nurse understaffing in nosocomial viral gastrointestinal infections on a general pediatrics ward. *Infect Control Hosp Epidemiol* 2002;23:133-6.
  23. MACARTNEY KK, GORELICK MH, MANNING ML, HODINKA RL, BELL LM. Nosocomial respiratory syncytial virus infections: the cost-effectiveness and cost-benefit of infection control. *Pediatrics* 2000;106:520-6.
  24. World Health Organization. Infection Prevention and Control of Epidemic-and Pandemic Prone Acute Respiratory Diseases in Health Care. WHO/CDS/EPR/2007.6. June 2007 [cited 2008 Oct 1]. Available from: [http://www.who.int/csr/resources/publications/WHO\\_CD\\_EPR\\_2007\\_6/en/](http://www.who.int/csr/resources/publications/WHO_CD_EPR_2007_6/en/).
  25. CHANDRAN A, HEINZEN RR, SANTOSHAM M, SIBERRY GK. Nosocomial rotavirus infections: a systematic review. *J Pediatr* 2006;149:441-7.
  26. WRIGHT ML, ROMANO MJ. Ventilator-associated pneumonia in children. *Semin Pediatr Infect Dis* 2006;17:58-64.
  27. FAYON MJ, TUCCI M, LACROIX J, et al. Nosocomial pneumonia and tracheitis in a pediatric intensive care unit: a prospective study. *Am J Respir Crit Care Med* 1997;155:162-9.
  28. ELWARD AM, WARREN DK, FRASER VJ. Ventilator-associated pneumonia in pediatric intensive care unit patients: risk factors and outcomes. *Pediatrics* 2002;109:758-64.
  29. Institute for Healthcare Improvement. Prevent Ventilator-Associated Pneumonia. 2007 [cited 2008 Oct 1]. Available from: <http://www.ihp.org/IHI/Programs/Campaign/VAP.htm>.
  30. ALY H, BADAWY M, EL KHOLY A, NABIL R, MOHAMED A. Randomized, controlled trial on tracheal colonization of ventilated infants: can gravity prevent ventilator-associated pneumonia? *Pediatrics* 2008;122:770-4.
  31. Institute for Healthcare Improvement. Prevent central line-associated bloodstream infections. 2007 [cited 2008 Oct 1]. Available from: <http://www.ihp.org/IHI/Programs/Campaign/CentralLineInfection.htm>.
  32. BUCKLEY J, COFFIN SE, LAUTENBACH E, et al. Outcome of *Escherichia coli* and/or *Klebsiella* bloodstream infection in children with central venous catheters. *Infect Control Hosp Epidemiol* 2007;28:1308-10.
  33. BROOKER RW, KEENAN WJ. Catheter related bloodstream infection following PICC removal in preterm infants. *J Perinatol* 2007;27:171-4.
  34. MATLOW AG, WRAY RD, COX PN. Nosocomial urinary tract infections in children in a pediatric intensive care unit: a follow-up after 10 years. *Pediatr Crit Care Med* 2003;4:74-7.
  35. Institute for Healthcare Improvement. Prevent Surgical Site Infections. 2007 [cited 2008 Oct 1]. Available from: <http://www.ihp.org/IHI/Programs/Campaign/SSI.htm>.

36. Zaoutis TE, Goyal M, Chu JH, et al. Risk factors for and outcomes of bloodstream infection caused by extended-spectrum beta-lactamase-producing *Escherichia coli* and *Klebsiella* species in children. *Pediatrics* 2005;115:942-9.
37. Asensio A, Oliver A, Gonzalez-Diego P, et al. Outbreak of a multiresistant *Klebsiella pneumoniae* strain in an intensive care unit: antibiotic use as risk factor for colonization and infection. *Clin Infect Dis* 2000;30:55-60.
38. Zingg W, Posfay-Barbe KM, Pittet D. Healthcare-associated infections in neonates. *Curr Opin Infect Dis* 2008;21:228-34.
39. Foglia E, Meier MD, Elward A. Ventilator-associated pneumonia in neonatal and pediatric intensive care unit patients. *Clin Microbiol Rev* 2007;20:409-25, table.
40. Apisarnthanarak A, Holzmann-Pazgal G, Hamvas A, Olsen MA, Fraser VJ. Ventilator-associated pneumonia in extremely preterm neonates in a neonatal intensive care unit: characteristics, risk factors, and outcomes. *Pediatrics* 2003;112:1283-9.
41. Schelonka RL, Scruggs S, Nichols K, Dimmitt RA, Carlo WA. Sustained reductions in neonatal nosocomial infection rates following a comprehensive infection control intervention. *J Perinatol* 2006;26:176-9.
42. Lobo RD, Levin AS, Gomes LM, et al. Impact of an educational program and policy changes on decreasing catheter-associated bloodstream infections in a medical intensive care unit in Brazil. *Am J Infect Control* 2005;33:83-7.
43. Pessoa-Silva CL, Hugonnet S, Pfister R, et al. Reduction of health care associated infection risk in neonates by successful hand hygiene promotion. *Pediatrics* 2007;120:e382-90.
44. Webster J, Pritchard MA. Gowning by attendants and visitors in newborn nurseries for prevention of neonatal morbidity and mortality. *Cochrane Database Syst Rev* 2003;(3):CD003670.