

Nosocomial Infections in the Pediatric Intensive Care Unit

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Nosocomial (hospital-acquired) infections are a major complication of serious illnesses. Severely ill patients have a greater risk of acquiring nosocomial infections, so this problem is greatest in intensive care units. Studies have demonstrated that nosocomial infections are largely preventable. Adherence to recommended techniques for patient care will have the greatest benefit in the intensive care unit. In this paper the background epidemiology of nosocomial infections is reviewed and related to pediatrics and intensive care units. Types of diseases, assistance equipment, and monitoring devices which are associated with a high risk of nosocomial infections are emphasized and specific steps for lowering this risk are listed.

INTRODUCTION

In the practice of critical care medicine, patients are brought together who have a very high risk for the development of nosocomial (hospital-acquired) infections. They are at increased risk because of the severity and possible immunosuppressive nature of their illness, and their need for invasive monitoring and life-support equipment. Although there have not been studies of infection rates specifically in *pediatric* intensive care units that care for children beyond the neonatal period, the epidemiologic factors which are associated with high susceptibility to nosocomial infection have been studied in adults and children.

Epidemiology and Rate of Nosocomial Infections

Several studies have established the expected *rates* of nosocomial infections in children hospitalized in general care wards and have defined the most common types of nosocomial infections, the organisms responsible, and the risk factors. Rates of nosocomial infections have generally been defined as the number of nosocomial infections divided by the number of patients at risk.

In the United States it has been estimated that one-third of infections in hospitalized patients are nosocomial. Thus, nosocomial infections occur in 1.5 million patients per year with a direct cost of one billion dollars [1].

In the early 1960s, T.E. Roy et al. [2] reported on an extensive survey of hospital infections at the Hospital for Sick Children in Toronto, Ontario. They reviewed 17,836 admissions. This included all pediatric patients; medical admissions outnumbered surgical admissions by a slight margin. They found a 6.5 percent overall rate of hospital-acquired infections. This figure is somewhat higher than the rate of 3.2 percent reported from Boston Children's Hospital Medical Center in 1970, in which there were twice as many surgical patients as medical patients [3]. In both

studies the rates were substantially higher on those services that dealt with debilitated patients and certain types of surgical patients. In the Toronto study, the two surgical wards had rates of 10.55 percent and 24.64 percent; however, rates were lower than average when surgery was performed on "clean" sites (2.1 percent). (Clean surgical cases are those in which there is an incision through prepared normal skin and the operative field does not include infected tissue, abscess, or entry into normally unsterile areas such as the bowel, the upper respiratory tract, or the lower female genital tract.) The Boston study paralleled the Toronto study in that higher than average rates were found among debilitated patients (tumor therapy ward, 21.4 percent) and surgical patients (neurosurgery, 18.5 percent) but they were lower than average on services whose patients enjoyed good general health and had short hospital stays such as dental, ophthalmology, and otolaryngology patients.

The latest available data on nosocomial infections in the United States state that the overall rate was 3.37 percent in 1978 and on pediatric services it was 1.2 percent. The sites of infection were more commonly the gastrointestinal tract and the respiratory tract in children than in adults [4]. There are no national data specifically giving nosocomial infection rates in pediatric intensive care units. The pediatric population which has recently been studied extensively is the patients in the neonatal ICU. Hemming et al. [5] reported a high rate of nosocomial infections (24.6 percent) at the University of Utah Medical Center, neonatal regional ICU for infants hospitalized for greater than 48 hours. By comparison, the nosocomial infection rate for the entire hospital was 7.3 percent. It was 5.4 percent for the general pediatric ward and 0.6 percent for the well-baby nursery. In another recent study of nosocomial infection in a neonatal ICU it was hypothesized that proper staffing, adequate working space around incubators, control of traffic flow, and the presence of convenient scrub areas would decrease the rate of nosocomial infections. This was confirmed in a prospective study when a new nursery was built with improvements in all of these areas. The nosocomial infection rate for *serious* infections fell from 5.2 percent to 0.9 percent [6].

While specific nosocomial infection rates for patients in pediatric intensive care units outside of the neonatal period have not been published, there are data for adult ICUs. In a representative study Northey et al. [7] reported a nosocomial infection rate of 23.4 percent among patients in an adult surgical intensive care unit. Upper respiratory and urinary tract infections were the most common. If one takes into consideration the published nosocomial infection rates in pediatric patients with the underlying predisposing illnesses similar to patients in a pediatric ICU and the data for neonatal and adult ICUs, 20 percent is a good approximation of the expected rate in a pediatric ICU.

The sites of nosocomial infections vary depending on the population. In a neonatal ICU the most common sites are the skin, lower respiratory tract, blood, and wounds, in that order. The rates are higher in low birth-weight infants. *Staphylococcus aureus* and gram-negative rods are the most common bacterial species. In the Toronto study, the most common sites were respiratory and gastrointestinal. Again, staphylococci (70 percent) and gram-negative rods accounted for most of the infections [2]. In the study conducted at Boston's Children's Hospital Medical Center, the most common sites were wounds, urinary tract, and respiratory tract, in that order. The most common organisms encountered were *Staphylococcus aureus*, *Staphylococcus epidermidis*, and group A *Streptococcus* [3].

Risk of Nosocomial Infections

General Risk Factors Several studies have addressed the question of the risk factors associated with the development of nosocomial infections. Studies from the Denver Veterans Administration Hospital attempted to quantify the factors associated with risk of infection from a strain of *Klebsiella pneumoniae*, which was the cause of a large cluster of nosocomial infections, primarily in ICU patients, and was resistant to multiple antibiotics [8,9]. They found that asymptomatic gastrointestinal colonization frequently preceded manifest infection. In a prevalence study, it was shown that 18 percent of those who were GI carriers of the *Klebsiella* strain had an infection due to the organism during their admission, while only 3 percent of those who were not colonized were infected. In a separate prospective longitudinal study, those who became carriers of *Klebsiella* during hospitalization, but were culture-negative on admission, had a 48 percent incidence of nosocomial *Klebsiella* infection. Length of hospitalization was another major factor. The rate of colonization rose steeply after three days of hospitalization to a maximum prevalence of 66 percent for those who were hospitalized for longer than 30 days. The therapeutic interventions associated with acquisition of *Klebsiella* in the gastrointestinal tract were inhalation therapy, nasogastric suction, and antibiotic therapy. These factors probably account for the high rates of nosocomial infections in patients who have been in an ICU. These findings have been validated in subsequent studies [10,11].

Colonization of the upper respiratory tract with hospital-acquired flora is also associated with the development of nosocomial infections. The prevalence of pharyngeal colonization with gram-negative bacilli was studied by Johanson et al. [12]. Colonization rate was proportional to the estimated *degree* of illness: it was low (2 percent) in physiologically normal inpatients and non-hospitalized normal subjects; moderately ill patients had a 16 percent rate of colonization, and moribund patients had a rate of 57 percent. It was assumed that the sicker patients had defective clearance mechanisms and that they also had more contact with contaminated materials. Patients receiving antibiotics also had a higher prevalence of gram-negative bacilli in the pharynx. This is attributed to the suppression of normal flora by antibiotics, allowing new organisms to colonize mucosal surfaces. Although pharyngeal colonization does not mean that there is active infection, it frequently precedes invasion, especially in patients who aspirate or already have other respiratory infections.

The use of intravascular catheters and intravenous (IV) infusions are frequently implicated in the development of nosocomial infections. Septicemia rates associated with IV cannulae have varied in studies from 0 to 8 percent. The care of the infusion set and the cannulation site are important variables [13]. Subsequent reports have shown that the degree of risk is related to the method of insertion, type of catheter, type of infusion, and, to a very large extent, duration of catheter placement. There have been extensive studies of colonization of the catheter insertion site in the skin but it is related only indirectly to the development of sepsis. Bloodstream invasion, local skin infection, thrombophlebitis, and a particularly virulent form of septic thrombophlebitis are associated with IV catheters in the critically ill [14].

The factors predisposing to urinary tract infection are related to instrumentation (including surgery) and indwelling urethral catheters. In a study from Salt Lake City, Utah, the factors associated with the development of catheter-associated infec-

tions were studied. All of these patients had closed drainage equipment, which is considerably safer than open drainage and should be standard equipment. There was a higher rate of infection among females, the elderly, and the critically ill. Breaks in the closed system or improper care of the drainage bag predispose to bacteruria [15]. During the first eight days of catheterization the rate of bacteruria rose and then leveled off at about 50 percent. Previous systemic antibiotic use again tends to select for resistant bacteria rather than to prevent infection [16].

The discipline of the epidemiology of nosocomial infections is approaching a new level of sophistication. Recently, methods for assessing the risk of nosocomial infections have been developed which allow quantitation by the use of formulas which allow for multiple risk factors [17]. Using a method of "risk ratio" calculation, it was found that the daily risk of nosocomial infection was highest on the neurosurgical and thoracic surgery services, and pediatrics was one of the lowest. Patients with fractures and other trauma were at highest risk. Medical assistance equipment such as ventilators and invasive monitoring were also responsible for high risk. The use of endotracheal tubes, bladder catheters, and systemic antibiotics were associated with five to ten times the risk of infection than the absence of these. Although specific rates were not determined for the intensive care units, those highest risk factors are frequently associated with ICU care. This type of analysis has been used for study of the epidemiology of chronic diseases. In the future it will allow refined quantitative categorization of risk in order to evaluate interventions designed to lower rates and to detect deviations such as poor hygiene which result in higher than expected rates.

Specific Environmental Risk Factors A number of general principles of risk for nosocomial infections have been discussed above. In addition, there have been large numbers of reports of increased risk of nosocomial infections associated with environmental contamination. Many of these reports are relevant to the care of the critically ill in intensive care units.

Inhalation Equipment While there has been recognition for a long time that the use of inhalation equipment was associated with risk of nosocomial respiratory infection, the mechanism was unknown until the equipment itself was studied. In 1970, Pierce et al. [18] reported on the relationship between contamination of reservoir nebulizers and the occurrence of nosocomial necrotizing pneumonia. Aerosols from this type of equipment may contain large numbers of gram-negative bacilli which are blown from the contaminated reservoir fluid into the patient's respiratory tract. They found that daily decontamination of this equipment with 0.25 percent acetic acid virtually eliminated nosocomial gram-negative necrotizing pneumonias. Ethylene oxide has also been found to be effective for decontamination. Outbreaks of gram-negative pneumonia have been reported to be due to contaminated nebulized medication. The use of room humidifiers in the hospital has also been linked to the aerosolization of bacteria and colonization of exposed patients [19].

Intravenous Solutions and Catheters Infections associated with infected intravenous infusion sites and contaminated IV solutions have become a major source of concern for infection control physicians. All patients who require intravascular fluid therapy are at risk for infection from contaminated IV solutions, medication, and tubing. A tragic example of this risk was a large multi-state outbreak of infection due to *Erwinia* and *Enterobacter* from a defect in the manufacturing of the infusion bottles which was subsequently corrected. Many hospitals reported unexpected episodes of sepsis due to these species with rates of infection and death that

were related to the seriousness of the underlying diseases, although occasionally otherwise healthy patients were infected [20,21].

In-line pressure transducers have become recognized as potential sources of contamination. Prior to 1973 no episodes of infection had been linked to the use of pressure-monitoring devices. In 1973, there were reports of separate clusters of disease due to Epstein-Barr virus, *Pseudomonas cepacia*, and *Candida* caused by these devices. This prompted the CDC to develop recommendations for their care which included using only disposable chamber-domes [22]. However, outbreaks from units using disposable domes with built-in membranes have now been described. Seventeen patients at the University of Virginia Hospital intensive care unit developed bacteremia with *Serratia marcescens* after exposure to pressure-monitoring devices. Hand contamination at the time of assembly of the equipment was the probable mode of transmission in one case [23], and contamination from an auxiliary syringe and calibration device in another [24]. CDC recommendations for care of these devices have been revised [25], and warning has been given not to reuse disposable items [26].

Arterial lines also carry the risk of infection. An outbreak of bacteremia due to *Flavobacterium* species, Group II-B affecting 14 patients in an intensive care unit was traced to indwelling arterial catheters [27]. Monitoring can be performed safely using the radial artery if *reasonable precautions* are taken. These are outlined in the following section on control of nosocomial infection. In a prospective study at the University of Utah there were no infections in 531 patients with an average duration of catheterization of 3.7 days, when similar guidelines were followed [28].

Swan-Ganz catheters are another source of nosocomial infections. As with other intravascular devices, the risk of infection is related to the care taken at the time of insertion and the duration of use. Aseptic endocardial vegetations can occur with the use of these catheters [29] and septic endocarditis has been reported as well [30].

Viral Infection In pediatric practice, there is a great risk of nosocomial infection from *viruses*. Spread of viruses does not appear to be as clearly related to equipment, antibiotic use, or inanimate reservoirs as is found in bacterial infection. Almost any virus which is spread by the respiratory or the GI tracts can cause nosocomial infection if routine care techniques are not enforced or if a particularly infectious virus disease goes undetected. Recent surveillance studies have indicated certain viruses to be of special concern for nosocomial infections.

Respiratory syncytial virus has been shown in several studies by Hall and colleagues [31–33] to be a significant nosocomial pathogen in pediatric hospital units. Infection due to respiratory syncytial virus can cause significant disease in any infant and could be responsible for life-threatening decompensation in infants who are already in an unstable state. Acquisition was related to length of hospital stay, and infections were symptomatic. During a community outbreak, infants hospitalized longer than four weeks had a 100 percent infection rate [32]. Ward personnel are frequently infected and then spread the infection. In a recent study, hand transmission and close contact were shown to be responsible for dissemination to non-infected individuals; aerosols traveling a considerable distance were not a major factor. Hand washing as well as limiting of number of contacts were emphasized as a means of infection control [31].

Varicella (chickenpox) is often transmitted via aerosol dissemination. This viral infection is a particular threat to immunocompromised patients who can develop a progressive fulminant form of the disease which has a high mortality. In a recent

study, transmission occurred via the ventilation system [34]. Screening hospital personnel for antibody to varicella virus can pinpoint those individuals who could become infected and, who could, therefore, transmit chickenpox to patients at risk. Immunosuppressed patients who lack antibody to varicella virus must be isolated from any patients with chickenpox.

Diarrheal disease due to virus has long been noted to cause considerable morbidity in children's hospitals but only in the past few years have these viruses been identifiable. In addition to rotavirus which has been extensively studied in children, other viruses known as minirovirus and calicivirus have been identified in nosocomial infantile gastroenteritis [35]. These have not yet been implicated as causing a unique problem in ICUs.

Control of Nosocomial Infections

Physicians should be familiar with current recommendations concerning the control of the factors most frequently associated with transmission of these infections. Below are summaries of current recommendations concerning vascular catheters, urinary catheters, hand washing, and isolation techniques appropriate for critical care. The Centers for Disease Control is actively involved in the study of this problem and keeps the medical community informed about risk factors and control through the journal, *Morbidity and Mortality Weekly Report*.

General Measures Generally hospitals with specialized units for critically ill children will have an active infection surveillance and control program. The adoption of a hospital infection control officer position in most U.S. hospitals and routine administration of recommended infection control measures in most U.S. hospitals has been documented [36]. The administrator of the critical care unit should be familiar with the control officer and routinely review surveillance data to facilitate early recognition of deviations from the usual experience of the institution. Routine culturing of the environment, preparation of equipment, isolation techniques, and disinfection should be under the control of the surveillance and control team. The guidelines for these operations will not be dealt with here. These are available in the American Hospital Association's publication *Infection Control in the Hospital* [37] and the CDC's *Isolation Techniques for Use in Hospitals* [38].

Isolation Technique The appropriate isolation measures for specific diseases are detailed in the Center for Disease Control's *Isolation Techniques for Use in Hospitals* [38]. The components of each level of isolation are specified in that manual and summarized in Table 1. The type of isolation required for diseases commonly encountered in the ICU are indicated in Table 2. More detailed instructions for isolation technique for less commonly encountered disorders can be found in Gardner and Provine, *Manual of Acute Bacterial Infections* [39], and the revised CDC guidelines for isolation [40] which will soon be generally available.

Specific Measures: Intravenous Therapy

1. Intravenous cannulae should be inserted only when clearly indicated. In general, "keep open" intravenous infusion should be discouraged if it is for the convenience of the medical staff.

2. Steel needles rather than plastic catheters are generally preferred whenever possible. Their infection rate is much lower.

3. Intravenous cannulation of the lower extremities should be avoided, as this location has been associated with higher rates of infection.

TABLE 1
Infection Control Isolation Categories Recommended by the Center for Disease Control*

Isolation Category	Examples of Infection	Private Rooms	Gowns	Gloves	Mask	Secreta and Soiled Articles
Respiratory	Tuberculosis Meningococcal disease Measles	+			+	+
Wound and skin	<i>Staphylococcus aureus</i> or <i>Streptococcus pyogenes</i> wound Gas gangrene infections	D	(+)	(+)		+
Strict	Diphtheria <i>S. aureus</i> pneumonia	+	+	+	+	+
Enteric	Viral hepatitis Salmonellosis Shigellosis	Necessary for children	(+)	(+)		+**
Protective	Total neutrophil count $\leq 500/\text{mm}^3$	+	+	(+)	+	

*Adapted from [38]. These are general recommendations. Consult [40] for more detailed recommendations.

(+) For those persons with direct contact with patient or his dressings

D Desirable, but optional

**Excreta and soiled articles; blood precautions for hepatitis

4. Cannula insertion should be performed under aseptic conditions with effective antiseptics of the skin, preferably with tincture of iodine or iodophor, using sterile gloves and drapes if possible. Cannulae placed using other techniques under emergency conditions should be replaced as soon as possible.

5. Cannulae should be anchored to prevent to-and-fro movement. While local antibiotic ointment will reduce colonization of the puncture site with pathogenic bacteria, its efficacy in the prevention of sepsis is unknown and its use is elective.

6. The infusion site should be covered with a sterile dressing and the date and time of insertion should be noted.

7. IV administration sets should be changed every 24–48 hours [4,13].

8. IV cannulae should be changed at least every 48–72 hours.

9. IV infusion fluid should be changed at least every 24 hours.

10. Administration sets should be changed every 24 hours for total parenteral nutrition, central venous pressure monitoring, and intra-arterial pressure monitoring.

11. If local inflammation becomes evident at the site of IV placement, the whole system must immediately be replaced. If the patient becomes septic and another source is not determined, the infusion system should be suspect and empiric antibiotic therapy begun.

Specific Measures: Pressure-Monitoring Devices [22]

1. One of the most important aspects of controlling infection due to these devices is recognition of risk. Education of the medical staff as to the hazards of these devices is essential for compliance.

TABLE 2
Recommendations for Appropriate Isolation Techniques for Selected Diseases*

Disease	Type	Duration
Arthropod-borne viral encephalitides (eastern and western equine encephalomyelitis, St. Louis and Venezuelan equine encephalitis)	None	
Arthropod-borne viral fevers (dengue, yellow fever, Colorado tick fever)	BP	DH
Brucellosis: Draining lesions	SeP	DI
Other	None	
Burn wound	SI, WSP, or SeP (depends on extent)	DI
Candidiasis: Moniliasis, thrush	None*	
Other	None	
Chickenpox (varicella)	SI	DI: for immunosuppressed hosts 3 weeks after exposure for asymptomatic susceptibles
Cholera	EnP	DI
Closed cavity infection: Draining	SeP	DI
Not draining	None	
<i>Clostridium perfringens</i> : Wound infection		
Gas gangrene	WSP	DI
Other	SeP	DI
Congenital rubella syndrome	SI	DH
Cryptococcosis	None	
Cytomegalovirus (congenital or immunosuppressed)	None	
Diarrhea, acute, etiology undetermined	EnP	DI
Diphtheria	SI	2 cultures negative
Eczema vaccinatum	SI	DI
Enterocolitis, staphylococcal	EnP	CN
Gastroenteritis, <i>E. coli</i> , <i>Salmonella</i> <i>Yersinia enterocolitica</i> <i>Salmonella typhi</i> , <i>Shigella</i>	EnP	3 cultures negative
Gonorrhea	SeP	U
Hepatitis, type A, type B	EnP, BP/BF	DH
Hepatitis, B-antigen carrier, and non A, non B	BP/BF	DH
Herpes virus, disseminated neonatal	SI	DI
Herpes virus mucocutaneous	SeP	DI
Infectious mononucleosis	None*	
Influenza	None	
Listeriosis	SeP	DI
Malaria	BP	DH
Measles	RI	4 days after onset of rash
Meningitis		
Aseptic	ExP	DH
<i>Neisseria meningitidis</i>	RI	U
<i>Hemophilus influenzae</i>	RI**	U
Other	None	
Meningococemia, menin. pneumonia	RI	U
Mumps	RI	9 days after onset of swelling
Mycobacteria, atypical	None	
Mycoplasma pneumonia	RI (for children— optional)**	DI

TABLE 2—Continued

Disease	Type	Duration
Pertussis	RI	7 days after effective antibiotic or 3 weeks after onset of paroxysms
Plague		
Bubonic	WSP	CN
Pneumonic	SI	CN
Pneumonia, bacterial, not listed elsewhere	None*	
Mycoplasma	RI (for children—optional)**	DI
<i>Pneumocystis carinii</i> , Legionella	None	
<i>Staphylococcus aureus</i>	SI	DI
<i>Streptococcus</i> , group A	SI	U
Viral	SeP, RI (children)**	DI
Rabies	SI	DI
Rickettsial fevers, including	None	
Rocky Mountain spotted fever		
Rubella (acquired)	RI	5 days after onset of rash
Staphylococcal disease	SI	DI
Pneumonia draining lung abscess, severe skin or wound infection		
Streptococcal disease, group A		
Pharyngitis, scarlet fever	SeP	U
Pneumonia, extensive burn, skin, or wound infection	SI	U
Tetanus	None	
Toxoplasmosis	None	
Tuberculosis, pulmonary	RI	Until effective therapy established
Extrapulmonary, draining lesion	SeP	DI
Typhoid fever	EnP	3 negative stool cultures
Vaccinia, generalized and progressive	SI	DI

Information from [38]

*Downgrades the extent of isolation recommended in [38] based upon revision in [40]

**Upgrades isolation technique from recommendations in above manual, from no isolation recommended. See [40].

Type of Isolation or Precautions

- BP—Blood precautions
- EnP—Enteric precautions
- ExP—Excretion precautions
- BF—Body fluids
- RI—Respiratory isolation
- SeP—Secretion precautions
- SI—Strict isolation
- WSP—Wound and skin precautions

Duration of Isolation or Precautions

- CN—Until off antibiotics and culture-negative
- DH—Duration of hospitalization
- DI—Duration of illness (with wounds or lesions, DI means until they stop draining)
- U—Until 24 hours after initiation of effective therapy

2. Transducers should be cleaned with soap and water, rinsed, and then sterilized with ethylene oxide or glutaraldehyde between uses. Disposable “chamber domes” should not be reused.

3. Only experienced personnel should calibrate the instrument.

4. If possible, systems should not be opened for routine blood drawing, administration of medications, or other procedures. Each junctural break brings additional risk of infection.

5. Use of a sterile heparinized solution administered by a continuous flush may help maintain catheter function and decrease need for manipulations.
6. There should be frequent replacement of catheter and connecting equipment according to the guidelines for IV infusions.

Specific Measures: Urinary Catheters [41]

1. Indwelling urinary catheters should be used only when medically indicated.
2. They should be inserted only by adequately trained individuals, preferably a team trained for insertion and maintenance.
3. Catheters should be aseptically inserted, using sterile gloves, fenestrated drape, sponges, iodophor cleansing solution, and lubricant jelly. Catheters should be secured to prevent to-and-fro movement and traction.
4. Once or twice a day, catheter patients should have cleansing of the meatal-catheter junction with an antiseptic soap and application of an antimicrobial ointment.
5. A sterile closed drainage system should always be used. Any breaks in continuity of the system should be avoided. If irrigations are to be performed, a triple-lumen catheter should be used whenever possible.
6. Urine for culture should be aspirated from the distal catheter using a syringe and needle after the catheter is disinfected. Other urine specimens should be obtained from the drainage bag.
7. The collecting system must be downhill with bags always remaining below the level of the bladder.
8. Closed collecting systems should be replaced if there is inadvertent contamination or a break in the system.
9. Routine use of antibiotic irrigation in a well-maintained *closed* system is not indicated and in one study resulted in an increase of bacteruria. [16].

Specific Measures: Hand Washing Practices [42]

1. Hand washing with antiseptic preparations should precede surgery and other invasive procedures such as catheterization. Washing with soap and water between routine (non-surgical) patient contacts is sufficient. A recent report indicates that even this simple directive was insufficiently adhered to by medical personnel in one ICU [43]. Adherence to this recommendation is probably the least expensive, most effective means of reducing the rate of nosocomial infections.
2. For hand washing, other than pre-surgical scrubs, hands should be vigorously lathered and rubbed together for at least 15 seconds with soap and warm running water. Hands should be rinsed and dried with a paper towel and the towel used to turn off the faucet.
3. Personnel should not wear rings or nail polish when on duty as these make removal of organisms more difficult.
4. Hands should be washed with soap and water after contact with patient excretions, secretions, or blood.
5. Washing should precede care for intravenous, urinary, or peritoneal catheters, or other invasive devices. Gloves should be put on before the insertion of catheters.
6. Because of high susceptibility of ICU patients to nosocomial infection, personnel working in these units need to wash their hands more often than personnel in

most other areas. Nevertheless hand washing with soap and water should suffice before most routine contacts.

7. Personnel with dermatitis which may be caused by frequent hand washing are likely to be a greater risk to patients. Such personnel may wear gloves during duty and wash gloves between patient contacts. Creams should be applied *after* contact with patients as these creams are not sterile and may be a source for the spread of pathogens.

Specific Measures: Chickenpox Exposure

Despite the most meticulous screening policies patients who are in the incubation stages of varicella (chickenpox) and do not develop recognizable lesions until other susceptible patients have been exposed will be admitted to busy clinical units. Varicella-zoster immune globulin (VZIG) will prevent serious infection in immunocompromised susceptibles who have been exposed to active cases, if administered within 96 hours of exposure. The criteria for use of this material are listed below [44].

1. One of the following underlying illnesses or conditions:
 - (a) Leukemia or lymphoma
 - (b) Congenital or acquired immunodeficiency
 - (c) Immunosuppressive treatment
 - (d) Newborn of mother who had onset of chickenpox less than five days before delivery or within 48 hours after delivery
2. One of the following types of exposure to chickenpox or zoster patient(s):
 - (a) Household contact
 - (b) Playmate contact (more than one hour of play indoors)
 - (c) Hospital contact (in the same two- to four-bedroom or in adjacent beds on a large ward)
 - (d) Newborn contact (mother with onset of chickenpox less than five days before delivery or within 48 hours after delivery)
3. Negative or unknown prior history of chickenpox, or negative antibody titer
4. Age less than 15 years (with administration to older patients on an individual basis)
5. Less than 96 hours elapsed since exposure

Note Added in Proof

In a recently published study, the rate of nosocomial infections at Children's Hospital of Buffalo was 4.1 nosocomial infections per 100 patients discharged. The rate in the intensive care nursery unit was 22.2 infections per 100 discharges and the rate in the pediatric intensive care unit was 11.0 infections per 100 discharges [Welliver RC, McLaughlin S: Unique epidemiology of nosocomial infections in a children's hospital. *Am J Dis Child* 138:131-135, 1984]. This is fairly close to the estimates suggested in the text of this article.

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