Hospital-Acquired Infections in Intensive Care Unit Patients: An Overview with Emphasis on Epidemics

Richard P. Wenzel, MD, Robert L. Thompson, MD, Sandra M. Landry, RN, Brenda S. Russell, RN, Patti J. Miller, BA, Samuel Ponce de Leon, MD, Grayson B. Miller, Jr., MD

ABSTRACT

Surveillance activities for the detection of nosocomial infections at the University of Virginia Hospital (Charlottesville, Virginia) and at hospitals participating in the Virginia Statewide Infection Control Program have focused on outbreaks and device-related infections which are potentially preventable. Eleven outbreaks of nosocomial infections were identified at the University of Virginia Hospital between January 1, 1978 and December 31, 1982 (9.8 outbreaks/100,000 admissions). Ten of the 11 were centered in critical care units. The 269 patients involved in the epidemics represented 0.2% of all hospital admissions and 3.7% of all patients who developed nosocomial infections. Eight of the 11 outbreaks involved infection of the bloodstream, and the 90 patients who developed a bloodstream infection as part of an epidemic represented 8% of all patients with nosocomial bloodstream infections identified during the five-year study period. The reservoir of the 11 outbreaks involved devices (5), contaminated cocaine (1), probable blood products (1), other patients (3), and nursing personnel (1). Forty-one percent of all nosocomial bloodstream infections and 41% of all nosocomial pneumonias occurred in intensive care units (ICUs).

In 38 hospitals in the state of Virginia with ICUs and practitioners who voluntarily reported surveillance data between June 1, 1980 and May 31, 1982, there were 264,757 patients admitted and a crude infection rate of 3%. Of note is that 1,867 of the 7,407 nosocomial infections (25%) occurred in the ICU patients. Several factors point to a compelling argument that the highest priority in infection control resources be assigned to the prevention and control of ICU infections: ICU patients often have serious device-related infections and may be identified as high risk prior to infection. Furthermore, they are at risk of being infected as part of a major outbreak. Such characteristics define a population of hospitalized patients, many of whose infections are preventable.

INTRODUCTION

Nosocomial infections occur in 5% to 10% of patients admitted to hospitals in the US and result in increased morbidity, mortality, and costs. As a result, surveillance has been advocated by the Centers for Disease Control in order to develop priorities for research and infection control activities. Efforts to streamline surveillance methods have been advanced, and a concept of identifying "preventable" infections has evolved. In general, preventable infections are those related to a device or a specific procedure, in contrast to infections that do not occur after a specific procedure or use of a device and that often occur in immunosuppressed hosts. It has recently been suggested that a high priority for infection control be the identification of procedure-related infections in patients in intensive care units since a significant proportion of such infections may be preventable.

The purpose of this paper is to review infection surveillance data accumulated at the University of Virginia Hospital over a five-year period and to focus on epidemics of nosocomial infection. Data from a statewide surveillance and reporting program in Virginia are presented to examine the rates and proportions of nosocomial infections in intensive care units.

From the Departments of Medicine and Nursing, University of Virginia Medical School, Department of Epidemiology, University of Virginia, Graduate School of Arts and Sciences, Charlottesville, Virginia, and Virginia Commonwealth Health Department, Richmond, Virginia.

This work was supported in part by contract no. 5-30163 from the Virginia State Health Department.

Address reprint requests to Richard P. Wenzel, MD, Box 473, University of Virginia Medical Center, Charlottesville, VA 22908.
Methods and Materials

Hospital

The University of Virginia Hospital is a 700-bed teaching hospital serving the city of Charlottesville (population 40,000) and the western half of the state of Virginia. Approximately 20,000 patients are admitted annually for a mean hospitalization time of nine days.

There are five intensive care areas within the hospital, accounting for 8% of hospital beds: a surgical ICU (16 beds), a neonatal ICU (16 beds), a burn unit (6 beds), a medical ICU (8 beds), and a coronary care unit (8 beds). Both the surgical ICU and the burn unit are open wards without partitions to separate individual patients. In the neonatal ICU, up to six babies may be housed together. Patients have private or semi-private rooms in the medical ICU and in the coronary care unit.

Surveillance Programs

Local Surveillance

Hospital-wide surveillance has been performed since August 1972. Initially, each ward was visited weekly, and charts of high-risk patients were selected for review based on "clues" found in the nursing treatment Kardex, which lists individual patients, diagnoses, procedures performed, and special nursing instructions. Since 1975, additional surveillance has included the following: 1) surveys twice weekly of all ICUs and the obstetrics ward, and 2) laboratory-based surveillance of all bloodstream infections. The latter procedure was introduced to insure 100% sensitivity of surveillance for identifying nosocomial bloodstream infections. In mid-1978, an on-line computer-based system was introduced to allow storage and retrieval of data regarding procedure-related infections.

An outbreak was defined as a cluster of infections specific to a particular anatomic site occurring at a rate which when compared with the incidence of endemic disease due to the same site-specific pathogen(s), was significantly greater than expected (Fisher's exact test, P<0.05). Outbreaks of nosocomial infections at the University of Virginia Hospital occurring between January 1, 1978 and December 31, 1982 are reviewed.

Statewide Surveillance

A statewide system for surveillance and reporting of nosocomial infections has been described. The program is based on the Kardex surveillance method, and uniform definitions of infection are used. The monthly reporting frequency was demonstrated at 83%, and the sensitivity and specificity of the surveillance techniques were 69% and 99% respectively. In a subset of 38 hospitals with ICUs, and with practitioners who voluntarily reported surveillance data between June 1, 1980 and May 31, 1982, crude infection rates are reported. The proportion of nosocomial infections which occurred in ICUs is also shown. The 38 institutions in the current study represented one university hospital, seven community hospitals with<300 beds, 23 with 100 to 300 beds, six with<100 beds, and one federal hospital.

Results

University Hospital Surveillance

During the five-year study period, there were 111,290 admissions to the University of Virginia Hospital and 7,367 infections for a crude infection rate of 7%. Eleven outbreaks of nosocomial infections were identified (Figure), with ten occurring in ICUs. Two hundred and sixty-nine patients were involved in the epidemics, representing 0.2% of all hospital admissions and 3.7% of all patients who developed nosocomial infections.

Eight of the 11 outbreaks involved infection of the bloodstream (Table 1). Furthermore, the 90 patients who developed a bloodstream infection as part of an epidemic represented 8% of all patients with nosocomial bloodstream infections during the five-year study period. The reservoir of the 11 outbreaks involved devices in five instances, contaminated topical anesthetic solutions of cocaine in one, probable blood products in another, and other roommates in three instances. In one outbreak of Staphylococcus aureus skin infections in the Newborn ICU there was an association of dermatitis on the hands of seven nurses. The dermatitis was related to the excessive use (up to 30 times per shift) of a newly introduced handwashing agent containing an antiseptic.
TABLE 1

ELEVEN OUTBREAKS OF NOSOCOMIAL INFECTIONS—UNIVERSITY OF VIRGINIA HOSPITAL IDENTIFIED BY ROUTINE SURVEILLANCE BETWEEN JANUARY 1, 1978 and DECEMBER 1, 1982 ILLUSTRATING THE FREQUENT LOCATIONS IN INTENSIVE CARE UNITS

<table>
<thead>
<tr>
<th>Organism</th>
<th>Anatomic Site of Infections</th>
<th>Reservoir</th>
<th>Number of Deaths per Number of Patients</th>
<th>Unit*</th>
<th>Reference if Published</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Serratia marcescens</em></td>
<td>Bloodstream</td>
<td>Pressure monitor transducer head</td>
<td>10/19</td>
<td>SICU</td>
<td>22</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em> and <em>oxytoca</em></td>
<td>Bloodstream</td>
<td>Banked breastmilk (contaminated electric pump)</td>
<td>1/5</td>
<td>NICU</td>
<td>23</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>Bloodstream</td>
<td>Swan-Ganz catheter</td>
<td>0/4</td>
<td>CCU</td>
<td>24</td>
</tr>
<tr>
<td><em>Staphylococcus epidermidis</em></td>
<td>Bloodstream</td>
<td>Broviac catheter</td>
<td>0/5</td>
<td>NICU</td>
<td>24</td>
</tr>
<tr>
<td><em>Staphylococcus epidermidis</em></td>
<td>Bloodstream</td>
<td>Swan-Ganz and arterial catheters</td>
<td>3/6</td>
<td>MICU</td>
<td>25</td>
</tr>
<tr>
<td><em>Candida albicans</em></td>
<td>Multiple including bloodstream</td>
<td>Contaminated cocaine</td>
<td>5/56†</td>
<td>SICU</td>
<td>25</td>
</tr>
<tr>
<td><em>Pseudomonas cepacia</em></td>
<td>Bloodstream</td>
<td>Probable blood?</td>
<td>3/3</td>
<td>SICU</td>
<td>25</td>
</tr>
<tr>
<td><em>Pseudomonas putida</em></td>
<td>Bloodstream</td>
<td>Nursing personnel with dermatitis**</td>
<td>0/6</td>
<td>NICU</td>
<td>25</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>Skin</td>
<td>Patients (ward or roommates)</td>
<td>5/154</td>
<td>BU/SICU</td>
<td>26,27</td>
</tr>
<tr>
<td>Methicillin resistant</td>
<td>Multiple including bloodstream</td>
<td>Patients (ward or roommates)</td>
<td>0/8</td>
<td>NICU</td>
<td>25</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>Gastrointestinal tract</td>
<td>Patients (ward or roommates)</td>
<td>0/3</td>
<td>Pediatrics</td>
<td>27</td>
</tr>
<tr>
<td><em>Salmonella enteritidis</em></td>
<td>Gastrointestinal tract</td>
<td>Patients (ward or roommates)</td>
<td>0/3</td>
<td>Pediatrics</td>
<td>27</td>
</tr>
</tbody>
</table>

* Infections occurred solely or predominantly in the unit.
† The outbreak was a combination of epidemic and pseudoepidemic.
‡ Crude case fatality ratios which do not imply cause-effect relationship.
** The dermatitis in seven nurses was related to excessive use of a newly introduced antiseptic handwashing agent containing chlorhexidine.
SICU—surgical intensive care unit; NICU—newborn intensive care unit; CCU—coronary care unit; MICU—medical intensive care unit; BU—burn unit.

Of all 7,367 infections acquired in the hospital during the study period, 1,548 (26%) occurred in ICUs. It should be noted that 41% of all nosocomial bloodstream infections and 41% of all nosocomial pneumonias occurred in ICUs. Seventeen percent of wounds, 16% of all nosocomial urinary infections and 30% of “other” infections occurred in patients in critical care units.

**Statewide Surveillance**

In the 38 hospitals in the state of Virginia with ICUs and practitioners who regularly reported surveillance data between June 1, 1980 and May 31, 1982, there were 254,757 patients admitted and a crude infection rate of 3%. Of note is that 1,867 of 7,407 infections (25%) occurred in the ICU patients (Table 2).

There was a relatively high crude rate of infection (64 per 100 admissions) and rate of bloodstream infection (28 per 100 admissions) in the single Burn Unit population studied. In contrast, crude infection rates in other critical care areas were seven to eight per 100 surgical, neonatal and medical ICU populations in the state, five per 100 in combined medical-surgical units, and 1.5 per 100 in coronary care units. Bloodstream infection rates varied from 0.5 to 1.5 per 100 admissions in all ICUs except the Burn Unit.

Nosocomial pneumonias occurred at a rate of nine per 100 admissions in the Burn Unit, 0.5 per 100 in the coronary care unit populations and 1.5 to 2.5 per 100 in all other ICUs. In the Burn Unit population the rates of infection of wounds (15/100), of the urinary tract (7/100) and other sites (5/100) were relatively high compared to infection rates in patients in other types of units, reflecting the differences in underlying patient populations.

**DISCUSSION**

In an earlier study at the University of Virginia, the
surveillance data demonstrated reasons why the highest priority for allocation of resources for control of nosocomial infections should be assigned to programs for control of infection among patients in ICUs: 1) 33% to 45% of all nosocomial bloodstream infections occurred in patients residing in critical care units, which comprised only 8% of hospital beds; 2) patients in ICUs had rates of bloodstream infection up to 24 times greater than those of patients on wards; 3) up to 73% of patients in surgical ICUs had at least one intravascular device inserted in addition to a peripheral IV catheter; the use of multiple intravascular devices was a marker for high-risk patients, since 5% to 17% of such patients developed a nosocomial bloodstream infection; 4) the most efficient surveillance (number of nosocomial infections detected per hour of surveillance) was in ICUs.

We have extended our earlier studies to include a five-year period during which time we identified 11 major outbreaks of nosocomial infections. Since by definition, all are preventable and since ten of eleven occurred in ICUs and nine resulted in nosocomial bacteremias, evidence continues to accumulate that surveillance in critical care units should be a priority. Furthermore, all outbreaks involving life-threatening nosocomial bloodstream infections occurred in ICUs at the University of Virginia Hospital. Thus, in institutions with limited resources, practitioners should perform surveillance at least in the ICUs with the expectation that most nosocomial outbreaks would be recognized. Furthermore, since outbreaks of infection caused by multiply-antibiotic-resistant organisms are frequently recognized initially in ICU areas, the practitioner would likely be able to recognize such epidemics prior to spread to other patient care areas and allow early initiation of outbreak investigation and the development and institution of control measures.

Examination of the epidemic curve of nosocomial epidemics indicated no seasonal pattern, and epidemics occurred in all four quarters of the year. However, only one outbreak occurred in the second quarter during the five-year study, whereas two to four occurred in each of the other quarters. The 11 major outbreaks identified represented an attack rate of epidemics of nosocomial infection of 9.8 per 100,000 admissions. Thus, it is possible that hospitals with a relatively small number of admissions may have limited experience with such problems, especially those without ICUs. It should be noted that almost 4% of patients with a nosocomial infection at any site and 8% of patients with a bloodstream infection during the study period developed the infections as part of an epidemic.

Data from the statewide surveillance program in Virginia showed that 25% of all nosocomial infections occurred in ICUs, which represented only a small proportion of total hospital beds. The sample involved 64 ICUs and 605 months of surveillance. The reporting frequency of 58% for ICU data was lower than the 83% reporting of overall hospital crude infection rates noted earlier and may reflect the difficulties which practitioners have in gathering specific ICU surveillance data in a timely fashion as well as hospital-wide data. This is substantiated in part by the fact that the same hospitals in the current

**Table 2**

**Infection Rates in Intensive Care Units—Virginia Statewide Surveillance and Reporting Program 1980 to 1982**

<table>
<thead>
<tr>
<th>Type of Unit</th>
<th>Number of Units Contributing Data</th>
<th>Number of Units Reporting</th>
<th>Cumulative Admissions</th>
<th>Total Infections</th>
<th>Rate Blood</th>
<th>Blood POW</th>
<th>PULM Urinary Tract Infection</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burn Unit</td>
<td>1</td>
<td>24</td>
<td>170</td>
<td>108</td>
<td>64.0</td>
<td>28.0</td>
<td>10.0</td>
<td>5.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Surgical ICU</td>
<td>9</td>
<td>157</td>
<td>6,206</td>
<td>488</td>
<td>8.0</td>
<td>15.0</td>
<td>10.0</td>
<td>2.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Neonatal ICU</td>
<td>9</td>
<td>95</td>
<td>2,218</td>
<td>186</td>
<td>8.0</td>
<td>15.0</td>
<td>10.0</td>
<td>2.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Medical ICU</td>
<td>4</td>
<td>85</td>
<td>2,912</td>
<td>204</td>
<td>7.0</td>
<td>10.0</td>
<td>2.5</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Combined Unit</td>
<td>3</td>
<td>47</td>
<td>13,545</td>
<td>648</td>
<td>5.0</td>
<td>10.0</td>
<td>0.5</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Other (Neurosurgery, Pediatric Care)</td>
<td>31</td>
<td>213</td>
<td>1,742</td>
<td>648</td>
<td>5.0</td>
<td>10.0</td>
<td>0.5</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Coronary Care</td>
<td>13</td>
<td>41</td>
<td>9,888</td>
<td>149</td>
<td>1.5</td>
<td>10.0</td>
<td>2.5</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td>1,043</td>
<td>36,481</td>
<td>1,967</td>
<td>1.5</td>
<td>10.0</td>
<td>2.5</td>
<td>1.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* Total number of unit-months possible for reporting, beginning with the month of the first report received during the two-year study period.

POW = post-operative wound infection; PULM = pulmonary infection; UTI = urinary tract infection.
study which submitted ICU-specific infection data 58% of the possible reporting months also submitted overall hospital crude infection data 70% of possible reporting months.

Our experience leads us to propose suggestions regarding infection control measures designed to reduce infections in ICUs, all of which could be tested in prospective studies: 1) Design of ICUs should include plans to separate patients by wall partitions in order to minimize movement of personnel from patient to patient without proper handwashing. Sinks placed at the entrances (not in corners) of ICUs may improve compliance with protocols for handwashing. 2) One-to-one nurse-to-patient ratios 24 hours a day may significantly reduce cross-infection, particularly if clinical specimens are obtained properly by a well-trained nurse in charge rather than by several untrained technicians. In addition, management of medical devices may be optimized by limiting access to intravascular devices to the primary care nurse. 3) Spatial separation of ICU patients who require two or more systemic antibiotics may minimize transmission of antibiotic-resistant organisms to noncolonized patients in the ICU. 4) Recognition of device-related infections by clinicians may be aided by daily use of individual patient “flow sheets” listing all devices used, dates of insertion, and documentation of the need for continuation. 5) Surveillance and reporting of hospital-acquired infections should include a separate category for device-related infections. The infection control team should be notified of the introduction of all new devices and products, including handwashing agents, to facilitate early recognition of infectious complications associated with their use; 6) Educational efforts especially with respect to the insertion and management of devices may be very efficacious. Specifically, ICUs which limit the duration of certain devices may be able to show lower infection rates than those with longer periods of use. The development of strict protocols for use of devices could be evaluated.

REFERENCES