Infection Control — A Problem for Patient Safety

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Nosocomial, or hospital-acquired, infections (more appropriately called health care–associated infections) are today by far the most common complications affecting hospitalized patients. Indeed, the Harvard Medical Practice Study II found that a single type of nosocomial infection — surgical-wound infection — constituted the second-largest category of adverse events. Long considered the greatest risk that the hospital environment poses to patients, nosocomial infections abruptly became the province of public health officers at the time of a nationwide epidemic of hospital-based staphylococcal infections, in 1957 and 1958. Since then, the study and control of nosocomial infections have been profoundly shaped by the discipline of public health, with its emphasis on surveillance and epidemiologic methods. These infections are not only the most common types of adverse events in health care; they may also be the most studied.

Currently, between 5 and 10 percent of patients admitted to acute care hospitals acquire one or more infections, and the risks have steadily increased during recent decades (Table 1). These adverse events affect approximately 2 million patients each year in the United States, result in some 90,000 deaths, and add an estimated $4.5 to $5.7 billion per year to the costs of patient care. Infection control is therefore a critical component of patient safety. In this article I describe the common ground shared by these two disciplines. I also discuss the major problems in infection control, approaches to their solutions, the role of the National Nosocomial Infections Surveillance (NNIS) System of the Centers for Disease Control and Prevention (CDC) as a model, and the need for renewed commitment to and innovations in infection control to help ensure patient safety.

Four types of infection account for more than 80 percent of all nosocomial infections: urinary tract infection (usually catheter-associated), surgical-site infection, bloodstream infection (usually associated with the use of an intravascular device), and pneumonia (usually ventilator-associated) (Fig. 1). One fourth of nosocomial infections involve patients in intensive care units, and nearly 70 percent are due to microorganisms that are resistant to one or more antibiotics — an emerging public health crisis that is due in large part to indiscriminate use of antibiotics.

Nosocomial infections can also be ranked according to their frequencies, associated mortality rates, costs, and relative changes in frequency in recent years. Catheter-associated urinary tract infections are the most frequent (accounting for about 35 percent of nosocomial infections) but carry the lowest mortality and lowest cost. Surgical-site infections are second in frequency (about 20 percent) and third in cost. Bloodstream infections and pneumonia are less common (about 15 percent each) but are associated with much higher mortality and costs. Bloodstream infections and methicillin-resistant Staphylococcus aureus infections share notoriety for being both the highest-cost infections and the most rapidly increasing in frequency; the current incidence of bloodstream infections is nearly three times the incidence in 1975. The rates of both urinary tract

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**Table 1. Nosocomial Infections in the United States.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Year 1975</th>
<th>Year 1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of admissions (x10⁶)</td>
<td>37.7</td>
<td>35.9</td>
</tr>
<tr>
<td>No. of patient-days (x10⁶)</td>
<td>299.0</td>
<td>190.0</td>
</tr>
<tr>
<td>Average length of stay (days)</td>
<td>7.9</td>
<td>5.3</td>
</tr>
<tr>
<td>No. of inpatient surgical procedures (x10⁶)</td>
<td>18.3</td>
<td>13.3</td>
</tr>
<tr>
<td>No. of nosocomial infections (x10⁶)</td>
<td>2.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Incidence of nosocomial infections (no. per 1000 patient-days)</td>
<td>7.2</td>
<td>9.8</td>
</tr>
</tbody>
</table>

Data are from Weinstein and Jarvis.©
and surgical-site infections have declined slightly, perhaps because of surveillance artifacts caused by decreases in the length of hospital stays and increasing numbers of infections that develop after discharge from the hospital.

Each of the main types of infection comprises more than one syndrome and has multiple pathogenic pathways. For example, ventilator-associated pneumonia, a cause of one fourth of the deaths attributed to nosocomial infections, commonly occurs as a result of infection with one or more bacterial species, but it may also occur with less common pathogens, such as legionella, respiratory viruses, or Aspergillus fumigatus. For each of the device-associated infections, multiple risk factors are related to the patient, the personnel caring for the patient, the procedures they use, and the device itself.

Identification of risk factors permits elucidation of those that are alterable from those that are not and facilitates the development of targeted interventions to reduce the risk of infection. For example, avoiding the use of invasive devices altogether by means of alternative strategies (for example, performing urinary drainage by condom catheter) and shortening the duration of use of the device (for example, reducing the number of days of mechanical ventilation) have been proposed in many guidelines. Strategies to prevent infections have been subdivided into several groups (education-based, process-based, and systems-based), but many of the suggested interventions — such as “use antibiotics wisely” or “educate and train staff” — have been vague and difficult to implement.

Behavioral change remains a formidable obstacle. For example, cross-infection of patients by health care workers with contaminated hands is a major source of infections. Despite educational efforts, health care workers, including physicians, continue to fail to adhere to standards for hand hygiene, which is universally considered the single most important method for infection control. The average level of compliance has varied among hospitals from 16 percent to 81 percent. Barriers to compliance include understaffing and poor design of facilities, confusing and impractical guidelines and policies, failure to apply behavioral-change theory fully, and insufficient commitment and enforcement by infection-control personnel. Remarkably, the use of waterless antiseptic hand rubs, when part of a multifaceted campaign that encourages appropriate hand washing, has been shown to be more practical than standard hand washing alone and has been shown to improve the adherence of health care workers to hand-hygiene guidelines and to prevent the transmission of methicillin-resistant S. aureus to patients.

The new Guideline for Hand Hygiene in Healthcare Settings, developed by a multidisciplinary task force, may facilitate system improvements by resolving many inconsistencies among previous guidelines from the CDC and other groups. It also includes a requirement for monitoring adherence to the guideline, along with suggested methods for doing so. The guideline bans the use of artificial nails when providing patient care, defines the different indications for hand washing as opposed to decontamination, and calls for the use of alcohol-based, waterless antiseptics for decontaminating the hands before and after any direct contact with a patient’s intact skin.

The history of infection control is littered with commercial products and devices to prevent infec-

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**PREVENTION OF NOSOCOMIAL INFECTIONS**

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**Figure 1. Number of Nosocomial Pathogens, According to Infection Site, Identified in the Hospital-Wide Component of the National Nosocomial Infections Surveillance System from January 1990 to March 1996.**

The hospital-wide component of the National Nosocomial Infections Surveillance System consists of a subgroup of hospitals reporting data on nosocomial infections from all patients. In January 1999, this component was eliminated from the system.
tion that were widely promoted after limited testing and have since been discredited. The development of safer devices (for example, needles with safety features and antimicrobial-coated catheters) has produced incremental gains in infection control, but devices constructed of biomaterials that fully prevent infections remain a tantalizing prospect. Conversely, the actual infection-control benefits of many technological improvements that were not designed primarily to prevent infections, such as improvements in anesthesia equipment and practice, are inestimable but probably great.

Because of the limitations of infection-control methods, the fundamentals of prevention have necessarily been grounded in epidemiology through the development of standard definitions and classifications; surveillance and early reporting of infections, with feedback to “those who need to know” (i.e., responsible authorities); evaluation of risk-based interventions; and production of evidence-based guidelines. This process has been guided by the CDC, with the help of the American Hospital Association and the regulatory efforts of the Joint Commission on Accreditation of Healthcare Organizations.

Epidemiologic analysis, often by means of case-control studies, is a powerful tool for identifying the cause or source of nosocomial infections. One example among hundreds is the recognition of a hospital outbreak in which 11 cases of neonatal sepsis over a period of four years were traced to a single human carrier. Root-cause analysis of individual cases would have been incapable of identifying the source of these or most other hospital infections. Another example is the recognition of erroneous handling of closed urinary-drainage systems as a cause of catheter-associated urinary tract infections. In this analysis, too, there was epidemiologic evidence of the importance of errors, even though most of the errors were not followed by infection. Moreover, voluntary reporting of frequently occurring infections has been found to underestimate greatly the true rate of avoidable infections, because most infections are considered unfortunate, inevitable consequences of medical procedures.

Active surveillance is necessary to identify alterable risk factors (sometimes called process indicators). Various indicators for infection control have been extensively evaluated, for example, in the development of a collaborative project to monitor health care processes and outcomes. The growing importance of monitoring process indicators is a benefited but major trend in infection control, but one that does not diminish the need for surveillance of outcomes. Without surveillance, we will not know the effect of our efforts to prevent infection. Two examples illustrate the value and limitations of process indicators and the need for continued surveillance: surgical-site infections and outbreaks in hospitals.

**SURGICAL-SITE INFECTIONS**

Many quality-improvement projects have identified errors in the administration of antibiotic prophylaxis before surgery as an independent risk factor for some postoperative infections. Incorrect timing of surgical prophylaxis is associated with increases by a factor of two to six in the rates of surgical-site infection for operative procedures in which prophylaxis is generally recommended. Failure to administer the first dose of antibiotic within the two-hour window before incision (to achieve adequate blood levels of the antibiotic during surgery) remains a common error, occurring, for example, in 27 to 54 percent of all selected operations in a 1996 New York State study. Effective programs have recognized and addressed the root causes of errors that result from faulty systems of care. In most patients who receive inappropriate prophylaxis, however, infections do not develop, and therefore relatively stable (and seemingly low) rates of surgical-site infections in an individual hospital can mask the problem and create complacency. Therefore, some limited monitoring of process indicators, such as timely prophylaxis, is necessary to detect system problems.

Improving the timing of antibiotic prophylaxis does not supersede other elements of infection control. In several early studies, surveillance of surgical-site infections with confidential feedback of the relevant data to surgeons was found to reduce the risk of infection. Regardless of the reasons for these results, the reasons for surveillance are no less pressing today and have additional justifications, with the use of ever more complex surgical procedures and with the development of most postoperative infections after discharge from the hospital. Voluntary reporting of wound infections by surgeons has not worked, and effective surveillance requires active identification of cases by trained personnel and consideration of the use of automated detection systems. The downsizing of many infection-control programs due to hospitals’ financial constraints has further increased the need for
new types of surveillance and process indicators to identify surgical-site infections.

OUTBREAKS IN HOSPITALS

At least 5 to 10 percent of infections occur in clusters, or outbreaks, that can be detected from careful review of surveillance information.\textsuperscript{30} Many outbreaks are recognized only by astute clinicians or laboratory workers. Most, if not all, infections in outbreaks can be construed as accidental injuries. Therefore, the detection, investigation, and control of outbreaks are a critical issue in patient safety and require vigilance.

Though occasionally dramatic, outbreaks may be insidious and may be protracted causes of substantial morbidity and mortality.\textsuperscript{21,31} They occur in all health care settings and with all classes of infectious agents, especially antibiotic-resistant bacteria, and because of their sometimes widespread nature, often have a considerable effect on the public. Of 114 health care–associated outbreaks investigated by CDC personnel over a 10-year period, 6 were national in scope and were traced to contaminated products or devices.\textsuperscript{32} Contamination of commercially distributed products may be detected only by spontaneous reporting from infection-control units in hospitals.

Recently, data-mining tools have been applied to detect previously unrecognized outbreaks.\textsuperscript{33} Molecular techniques have been used to show that seemingly unrelated infections have been caused by interspecies transfer of genes encoding antibiotic resistance, suggesting that the true rate of cross-infection in hospital settings remains greatly underestimated.\textsuperscript{34} These data indicate that the role of laboratory-based surveillance in public health is likely to increase.

THE PATIENT-SAFETY MOVEMENT

The importance of the patient-safety movement in energizing infection control is already manifest. Many infection-control units have broadened their activities in monitoring the use of antibiotics and in preventing adverse drug events due to antibiotics. (Antibiotic resistance may even be considered a special type of adverse drug event, one with societal consequences.)

More than 25 years ago, the Department of Clinical Epidemiology and Infectious Diseases of the LDS Hospital, in Salt Lake City, devised “clinical triggers” to facilitate the detection and surveillance of infections and to improve the use of isolation and barrier precautions for infection control.\textsuperscript{35} Also called “signals” or “alerts,” clinical triggers are elements drawn from patients’ electronic medical records by means of programmed logic or algorithms that suggest ongoing or potential adverse events, including infections. Continuous, real-time scanning of laboratory and pharmacy records, for example, facilitates cost-effective surveillance and active interventions to prevent or ameliorate adverse events. The LDS Hospital team monitored drug doses, renal function, the prescription of common antibiotics, and other triggers to track and prevent adverse drug events.\textsuperscript{36} Interventions by a clinical pharmacist reduced the use and misuse of antibiotics and showed that the potential to stabilize antibiotic resistance existed.\textsuperscript{37} Voluntary reporting of medication errors had little overlap with adverse drug events detected by this method. These concepts are now being widely adopted by hospitals across the country through collaborative efforts coordinated by the Institute for Healthcare Improvement.

Recently, the Agency for Healthcare Research and Quality released a controversial report that reviewed the evidence in favor of 79 patient-safety practices, of which 22 (28 percent) involved infection control.\textsuperscript{38} Further illustrating the common ground shared by these two disciplines, 5 of the 11 practices that were judged worthy of widespread implementation involved infection control. Two of these five practices — the appropriate use of antibiotic prophylaxis in surgical patients and the use of maximal sterile barriers during the placement of central venous catheters — were readily accepted. Curiously, the Agency for Healthcare Research and Quality reported that there was weaker evidence supporting methods to improve adherence to hand hygiene and limitations in antibiotic use — practices that some infection-control experts believe offer the greatest potential benefit. These and other infection-control practices were listed as priorities for further research.

IS THE NNIS SYSTEM A MODEL FOR INFECTION-CONTROL PROGRAMS?

The NNIS System of the CDC is a voluntary, confidential, hospital-based reporting system that has been influential in guiding infection-control efforts in hospitals across the United States and around the world; it is the only national source of systematically gathered data on hospital infections.\textsuperscript{39}
Monthly reports of nosocomial infections from more than 300 hospitals (a nonrandom sample of U.S. hospitals, all with at least 100 beds and nearly 60 percent academic medical centers) have allowed benchmarks for infection rates to be established through the use of standardized case definitions and data-collection methods and computerized data entry and analysis. Analysis of NNIS System data helps reveal changes in patterns of incidence, distribution, antibiotic resistance, sites of infection, outcomes, and risk factors for infection. In March 2000, the NNIS System reported that during the 1990s, the rates of infection for respiratory tract, urinary tract, and bloodstream sites, after adjustment for the duration of the use of invasive devices, had decreased in intensive care units in selected hospitals. The multiple reasons for these reductions, however, cannot be attributed to any specific interventions, nor does the report mean that all hospitals providing data to the NNIS System obtained these salutary results, since only a subgroup of hospitals participated.

The NNIS System is viewed as a benchmark on the basis of the reasonable expectation that the participating infection-control programs possess the components for effectiveness identified by the CDC in previous studies: intense surveillance, intense control measures, and an adequate number of infection-control professionals. Though not fully adjusted for patient risk factors, the rates of endemic infections in participating hospitals have been used to help drive improvement efforts. A few success stories have been reported from selected hospitals in which problems (such as excessive use of certain invasive devices and deviations from national guidelines) were identified and addressed, but evaluation is still incomplete.

Each hospital participating in the NNIS System provides data on only one or two high-risk components of surveillance, such as intensive care or selected surgical procedures. In addition, case ascertainment is time-consuming and costly for hospitals, and the definitions for infections are complex and difficult to apply. Therefore, the NNIS System is a model for focused surveillance but not for overall infection control. This system has not yet addressed many important safety issues, such as clinical errors of omission leading to failures to diagnose infection or delays in the diagnosis of infection. Furthermore, the definitions used during surveillance (for example, the definitions for ventilator-associated pneumonia and for infections developing after hospital discharge) are a work in progress.

Perhaps the most important outcome of the NNIS System is the infrastructure of trained infection-control professionals that it has nurtured and the cadre of CDC-trained infectious-disease physicians who have migrated to university and community hospitals during the past 30 years. These human resources are now endangered because of the economic forces shaping health care and the downsizing of many, if not most, infection-control units in hospitals. The voluntary nature of NNIS may be an important factor in its success, but participation also helps hospitals meet regulatory requirements.

In addition, the support of CDC epidemiologists is a vital asset. More than a decade ago, the Institute of Medicine called for further development of the NNIS System and its expansion to include more U.S. hospitals; indeed, the system has grown rapidly, from 120 hospitals in 1991 to more than 300 in 2001. The call for broader participation among all U.S. hospitals is even more urgent today.

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