The Changing Face of Surveillance for Health Care–Associated Infections

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Surveillance of health care–associated infections and antimicrobial resistance is an important aspect of prevention. In 2004, the Centers for Disease Control and Prevention had 3 national health care surveillance systems. During 2004–2005, these will be combined into a single Internet-based system, the National Healthcare Safety Network (NHSN). The NHSN will feature a number of enhancements, and ultimately, all US hospitals and other health care facilities will be encouraged to participate. Health care surveillance using standard methods has been very useful and is cited as a model for prevention. However, alternative approaches may improve health care surveillance by reducing complexity, decreasing the burden of data collection, and improving accuracy. These alternative approaches include adopting simpler methods and more-objective definitions, using sampling and estimation, substituting information in computer databases for manually collected data, and increasing surveillance for process measures with known prevention efficacy. Maintaining successful features of standard systems, adopting alternate surveillance approaches, and exploiting new technologies, such as the Internet, will make health care surveillance an even better tool for prevention.

Health care–associated infections (HAIs) and antimicrobial resistance are major problems in US health care institutions. Surveillance is a critical component of prevention efforts. Surveillance is defined as "the ongoing, systematic collection, analysis, interpretation, and dissemination of data regarding a health-related event for use in public health action to reduce morbidity and mortality and to improve health" [1, p. 2]. In the 1970s, the Study on the Efficacy of Nosocomial Infection Control (SENIC) showed that intensive surveillance, in combination with other aspects of an infection-control program, was associated with significantly reduced rates of HAI [2].

Since the 1970s, the Centers for Disease Control and Prevention (CDC) has conducted national surveillance programs for HAI. By 2004, three national health care surveillance systems were in operation, each focusing on different populations and events. During 2004–2005, these 3 systems will be combined into a single system, the National Healthcare Safety Network (NHSN).

To assist the CDC in making surveillance as effective as possible, the Healthcare Infection Control Practices Advisory Committee (HICPAC) will review NHSN periodically and advise on revisions and improvements. In this article, we will review the current CDC health care surveillance systems, describe plans for the new NHSN, and discuss alternate methods of surveillance, HAI definitions, risk adjustment issues, and plans to increase surveillance for process measures.

CURRENT CDC HEALTH CARE SURVEILLANCE SYSTEMS

National Nosocomial Infections Surveillance (NNIS) system.
For over 30 years, the NNIS system has been the primary national surveillance system for HAIs [3, 4]. The system was started in 1970 with 62 participating hospitals, and by 2000, it had expanded to >300 hospitals in 42 states. The primary goals of the NNIS system are to describe the epidemiology of HAI, establish benchmark comparison rates, and promote epidemiologically sound surveillance in hospitals. The approach was initially hospital-wide surveillance, but it changed in the mid-1990s to focused surveillance in high-risk units (e.g., intensive care units or high-risk nurseries) or patient populations (e.g., surgical patients); in addition, data on antimicrobial use and resistance are collected (table 1).

The NNIS system has produced scores of peer-reviewed publications, and the data are featured in numerous chapters
members reviewed charts with discrepant results [9]. For the 4 most commonly reported HAIs, the sensitivity was 59%–85%, and the positive predictive value was 72%–87%. This study [9] evaluated the ability of hospitals to use NNIS methods and was not a comparison with external “gold standard” definitions or methods.

National Surveillance System for Health Care Workers (NaSH). The NaSH collects information important for the prevention of occupational exposures and infections among health care personnel [10]. NaSH was established in 1995, and participation increased from 5 hospitals in 1995 to 52 hospitals in 2001. Data are collected for managing immunization and tuberculosis skin-testing programs; recording exposures to blood and body fluids, vaccine-preventable diseases, and tuberculosis; and determining levels of underreporting of percutaneous injuries. NaSH uses a Windows-based software tool for data entry and analysis, and data are submitted to CDC via computer diskette.

Dialysis surveillance network. The Dialysis Surveillance Network was formed in 1999 to track and reduce rates of infection in outpatients undergoing hemodialysis [11]. All outpatient dialysis centers in the United States are eligible for participation, and >140 centers have participated. In contrast to the previously described systems, an Internet-based data entry and analysis system is used. Events that lead to hospital admission, initiation of intravenous antimicrobial therapy, or a positive blood culture result are recorded. Criteria for infections are recorded rather than the occurrence of the infections themselves, allowing for simplified data collection and flexibility in defining events. Rates of several outcome variables are tracked and stratified according to type of vascular access, which is the most important risk factor for infection in this population. An evaluation of the accuracy of data collection is currently underway.

THE NATIONAL HEALTHCARE SAFETY NETWORK (NHSN)

The NHSN, which is scheduled to begin accepting data in late 2004, will integrate the 3 existing surveillance systems into a single Internet-based system. Although initially focused on hospitals and outpatient dialysis centers, the NHSN will be able to collect data from a variety of inpatient and outpatient health care settings. Compared with current systems, the NHSN will have a number of features to enhance data entry, analysis, and presentation. Streamlined data-reporting methods and increased capacity for upload of data from hospital databases will help to reduce the burden.

The NHSN will have 2 components: Patient Safety and Healthcare Worker Safety (table 1). The Patient Safety component will have 3 modules: the Device-Associated Module (for infections associated with invasive devices), the Procedure-
Table 2. Comparison of the National Nosocomial Infections Surveillance (NNIS) system and the planned Patient Safety component of the National Healthcare Safety Network (NHSN).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>NNIS system</th>
<th>NHSN</th>
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<tbody>
<tr>
<td>Enrollment requirements</td>
<td>Acute care hospitals</td>
<td>Internet access and e-mail address</td>
</tr>
<tr>
<td></td>
<td>&gt;100 Beds</td>
<td>Initially, acute care hospitals and chronic dialysis centers will participate</td>
</tr>
<tr>
<td></td>
<td>Infection control and FTE requirements</td>
<td>Later versions: any health care delivery venue may participate</td>
</tr>
<tr>
<td>Data transmission method</td>
<td>DOS-based IDEAS software</td>
<td>Internet-based</td>
</tr>
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<td></td>
<td>Phone modem transmission to CDC</td>
<td>Encrypted messaging</td>
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<td></td>
<td></td>
<td>User-friendly application</td>
</tr>
<tr>
<td>Reporting from ICUs or HRNs</td>
<td>All health care–associated infections monitored in selected ICUs/HRNs</td>
<td>Participants may monitor CLABSI, VAP, and/or CAUTI in selected ICUs/HRNs</td>
</tr>
<tr>
<td>Reporting from units other than ICUs and HRNs</td>
<td>Not included</td>
<td>Participants may monitor CLABSI, VAP, and/or CAUTI on selected specialty care areas and any other patient care location</td>
</tr>
<tr>
<td>Surgical patients</td>
<td>Inpatient operative procedures</td>
<td>Inpatient or outpatient operative procedures</td>
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<tr>
<td></td>
<td></td>
<td>Future versions will include nonoperative procedures (e.g., endoscopy)</td>
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<tr>
<td>Microbiology</td>
<td>Up to 4 pathogens</td>
<td>Participants may monitor up to 3 pathogens</td>
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<tr>
<td></td>
<td>Complete antibiogram required (all sensitivities)</td>
<td>Selected antibiograms for selected organisms</td>
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<td></td>
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<td>Limited number of required pathogen-agent combinations, but it may collect data on up to 20 agents per pathogen, if desired</td>
</tr>
<tr>
<td>Reporting of antimicrobial use and resistance</td>
<td>Required to monitor both microbiology and pharmacy</td>
<td>Participants may monitor microbiology and/or pharmacy</td>
</tr>
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<td>Developing the capacity to capture electronic data will facilitate data collection</td>
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NOTE. CAUTI, catheter-associated urinary tract infection; CLABSI, central line-associated bloodstream infection; DOS, disk operating system; FTE, full time equivalents; HRN, high-risk nursery; ICU, intensive care unit; IDEAS, Interactive Data Entry and Analysis System; VAP, ventilator-associated pneumonia.
which reduces comparability among different infection-control professionals. To overcome these disadvantages, alternate surveillance methods have been proposed. These methods hold promise of increasing data quality while decreasing burden, allowing time and energy to be directed toward prevention rather than data collection.

Surveillance for surgical site infections is a challenge, because approximately one-half of these infections present after hospital discharge [3]. One approach to postdischarge case-finding has been to use health plan computer files [12]. Application of computer algorithms to these electronic records yielded a sensitivity of 74% and a positive predictive value of 48%; it was possible to find 74% of infections by reviewing the 2% of patient charts that were flagged by the automated system.

This concept has been extended to finding surgical site infections that present during hospital admission. Two screening criteria (specific discharge diagnoses and days of postoperative antimicrobial receipt) were evaluated at 6 hospitals in the CDC Prevention Epicenters program [13]. The screening criteria had a sensitivity of 91% and a positive predictive value of 30%; in comparison, standard prospective surveillance had a sensitivity of only 59%. In addition to their use as a case-finding tool, the screening criteria could be a crude (sensitive, but with low predictive value) indicator of surgical site infection; if the number meeting the screening criteria exceeded a specified value or increased over time, chart review could be performed.

The value of using information in computer databases has been demonstrated for reporting of notifiable diseases to state health departments [14] and monitoring of HAI [15–17]. A recent study reported that computer flags for catheter-associated infections had a positive predictive value of 35% for bloodstream infections and of 38% for urinary tract infections [16]. Another study examined several alternative means of detecting central line–associated bloodstream infections [17]. The “gold standard” was chart review by study investigators using NNIS definitions. Available electronic data did not include whether the patient had a central line in place, so this factor could only be ascertained manually. The $\kappa$ values for agreement with the “gold standard” were 0.37 for routine prospective surveillance by infection-control professionals, 0.48 for a positive blood culture result plus manual determination of a central line, 0.49 for an algorithm based on information in computer databases, and 0.72 for the computer algorithm plus manual determination of a central line. Thus, even a very simple surrogate measure (positive blood culture result plus manual central line determination) had reasonable performance, but the best performance was achieved by a combination of the computer algorithm and manual methods.

These studies used alternative methods to implement the standard approach to surveillance—that is, to find defined events and to use appropriate denominators to calculate rates. Nonstandard approaches to surveillance include monitoring only the number of adverse events (without a denominator and rate calculation) or the time since last event. Another approach is to use data in computer databases and data-mining techniques to detect clusters of isolates that may indicate nosocomial transmission, so that infection-control action can be taken [18, 19]. These approaches may have value, especially if they are implemented in addition to standard methods.

It seems certain that the future of health care surveillance will involve the capture and use of data in existing electronic databases. These data could be used in case-finding to prompt a thorough chart review, populate certain fields in manual data entry screens, detect and calculate rates of surrogate events, or detect clusters. Surveillance for antimicrobial use through review of pharmacy records and for antimicrobial resistance through review of microbiology records is an obvious and direct application. These electronic data can also provide real-time feedback and decision support to clinicians at the point of care [20]. However, using these data is a very large undertaking [21] that involves getting permissions to access the data, standardizing the data elements, messaging the data using common and secure standard methods, and developing epidemiologic methods to use the data. Efforts on all of these fronts are currently being pursued by the CDC [22] and other groups in government and the private sector.

### DEFINITIONS OF HAI

Unfortunately, HAI cannot be easily defined. The NNIS system has definitions for 13 major site codes, each with 1–8 specific site codes; each specific site code has $\geq 1$ criteria; and each criterion may include several clinical, laboratory, and imaging features [3]. For example, the major site code for bloodstream infection includes 2 specific site codes (laboratory confirmed bloodstream infection and clinical sepsis); laboratory confirmed bloodstream infection has 3 criteria (2 for adults and 1 for infants). Subjective judgments are often required (e.g., nosocomial infections are those that were not present and not incubating at the time of admission, unless they are related to a previous admission). Ideally, only well-trained infection-control professionals should conduct surveillance using these definitions. Version 1 of the NHSN will include surveillance for only 4 of the major site codes (tables 1 and 2).

Standard definitions may be improved by substituting objective for subjective criteria (e.g., “positive blood culture $\geq 48$ h after admission” instead of “infection not present or incubating at admission”). Also, surveillance for surrogate events rather than HAI may be useful; the sensitivity and predictive value of these surrogates must be determined. Simpler definitions for HAI or surrogate events could make surveillance less burdensome and more reproducible among different data collectors at different institutions, possibly increasing overall
accuracy. A simplification of the surveillance methods and definition for bloodstream infections yielded acceptable accuracy [23]. The Dialysis Surveillance Network uses simple definitions that permit surveillance if a trained infection control professional is not available [11].

RISK ADJUSTMENT

Hospitals and their patient populations vary substantially, so it has become accepted to calculate and report risk-adjusted infection rates (i.e., rates that are adjusted for the most important known confounding factors). In the NNIS system, for device-associated infections, risk adjustment consists of calculating rates per 1000 device-days (e.g., the number of bloodstream infections per 1000 central line-days) and stratifying by unit type [3]. For surgical site infections, risk adjustment means calculation of operation-specific rates stratified by the NNIS surgical site infection risk index, which varies from 0 to 3 for most operations [3, 24]. These methods represent a compromise and do not account for all known potential confounding variables.

Risk adjustment is more important when making interfacility comparisons (“benchmarking”) than when tracking rates within a single institution. Benchmarking may have benefit in stimulating prevention programs at hospitals with high comparative rates, but it also may have the unwanted effect of discouraging prevention programs at hospitals with average or low rates.

In the future, information in computer databases should improve the accuracy and ease of risk adjustment. For the present, manual collection of data for risk adjustment is often time consuming, because data must be collected on the large population at risk, rather than only on the fraction having an HAI. Therefore, it is important to assess the impact of risk adjustment on interpretation of data (“How much difference does it make for how many hospitals?”) and explore ways to reduce the burden. To assess impact, we recently compared the risk of bloodstream infections as assessed by a crude rate (e.g., infections per 1000 patient-days) versus a gold standard rate (e.g., infections per 1000 central line-days) using data from the intensive care unit component of NNIS during 1995–2002; a median of only 6 infections were reported per unit per year [25]. As expected, we found that use of the line-day denominator makes a meaningful difference in assessed risk at many units. One approach to reducing burden is to use sampling and preliminary calculations suggest that continuing to count the number of patient-days but estimating total line-days from a sample of days or months is a promising approach that permits risk adjustment and substantially reduces the burden of collecting data on line-days.

Improved methods of risk adjustment that use automated methods are needed [12]. When manual data collection is required, questions regarding risk adjustment include the following: if the number of HAIs in a given unit is low, is risk adjustment worthwhile? How big a difference must risk adjustment make at how many institutions to justify the data collection burden at all institutions? And could time spent collecting data for risk adjustment be better spent on prevention activities?

DEVELOPING TOOLS TO MEASURE PATIENT CARE PROCESSES

Infection rates provide only limited information for guiding infection-prevention programs. Uncertainties about the preventable fraction of HAIs and current limitations in the science of risk adjustment create ambiguity about using infection rates to determine whether infection-prevention efforts are adequate in a given facility or unit. In addition, the infection rate itself provides no indication of what breaches in infection control might be contributing to the problem, and therefore, it provides no information on how best to focus prevention efforts. Another limitation is the small number of infections reported from many units.

Some of the limitations of outcome-based health care surveillance may be addressed by performing surveillance for patient care process measures that are known to directly influence HAI rates, such as appropriate selection and timing of preoperative antimicrobial prophylaxis or use of central venous catheter insertion practices that are proven to prevent catheter-associated bloodstream infections. First, such measures provide unambiguous performance targets; the goal should be adherence with proven practices for every eligible patient. Second, process measures enhance the ability to interpret findings from outcome-based surveillance and lead naturally to focused prevention efforts. Third, because measurable processes of care are common events relative to the infections, significant deviations in adherence are easier to detect than are significant deviations in infection. Lapses in infection control may therefore be recognized and addressed more quickly, potentially before an increase in the infection rate has occurred.

The use of process measures as performance indicators has been proposed in Healthcare Infection Control Practices Advisory Committee/CDC guidelines [26]. We have developed a tool for measuring procedures for insertion, maintenance, and appropriate use of central venous catheters and are conducting pilot tests to determine whether feedback of these data can increase adherence to recommended practices. We plan to create tools for additional process measures and to assess their impact on both adherence to guidelines and health outcomes.

CONCLUSIONS

For >30 years, CDC surveillance systems have recorded many successes as integral components of health care infection-
control programs. Key features associated with these successes include voluntary, confidential reporting; standardized definitions and methods; and scientific credibility. Challenges for the future include expanding surveillance beyond traditional intensive care unit and hospital boundaries, providing ongoing demonstrations of the prevention effectiveness of surveillance, increasing accuracy, and reducing the burden of manual data collection so that staff time can be used for prevention activities, such as improvements in process measures. Health care surveillance systems of the future can meet these challenges by maintaining successful traditional features while incorporating new and promising approaches.

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References