Measuring the Scope and Magnitude of Hospital-Associated Infection in the United States: The Value of Prevalence Surveys

Eloisa Llata, Robert P. Gaynes, and Scott Fridkin

Health care–associated infections are a major public health concern both in the United States and abroad, contributing to increased morbidity, mortality, and health care costs. As a consequence of changes in health care delivery and increasing demands on infection prevention, targeted surveillance has become common in the United States, focusing on areas of the hospital where a patient’s risk for health care–associated infection is greatest, as opposed to hospital-wide surveillance; the latter can be used to estimate the national burden of health care–associated infections. Many countries have shown that prevalence surveys can be used to quantify the burden of disease and to help establish priorities to accomplish national goals of prevention of health care–associated infection. Several different surveillance methods have been used, prohibiting comparisons of results among methods. We address some of these key differences and provide recommendations in areas that should be considered when designing a point prevalence survey in the United States.

The scope and magnitude of health care–associated infections (HAIs) are vast but difficult to enumerate with precision. At a cost of $27 million in the 1970s, the Study of the Efficacy of Nosocomial Infection Control (SENIC) [1] remains the most comprehensive US study of HAIs. The SENIC method included training data collectors for 1 month, on-site reviews of 1000 patient records in 338 randomly chosen US hospitals, and calculations of HAI rates for individual hospitals. From this study, a national 5% prevalence rate has been the estimate for the scope and magnitude of HAIs for >30 years, allowing additional estimates of cost burden (billions of dollars annually) and a national mortality estimate of nearly 90,000 deaths per year [2].

There is no uniform national reporting of all HAIs in the United States, in part because of the size of the health care provision system and variability in local HAI surveillance practice and needs. Past burden estimates have relied on sentinel surveillance networks. In the early 1990s, risk adjustment of infection rates and targeted surveillance became a primary focus of infection control efforts and remains central to HAI surveillance conducted by the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network, which focuses on high-risk patient groups (device-associated and procedure-associated HAIs) to produce risk-adjusted data for comparative purposes. Of note, recent state mandatory reporting laws may help to provide more robust estimates of HAIs from National Healthcare Safety Network in the coming years. However, in most instances, surveillance methods do not identify all HAIs useful for a national prevalence estimate. The last time the CDC estimated the scope and magnitude of HAIs, 1990–2002 National Nosocomial Infections Surveillance system data were used [3]. This analysis faced several methodological challenges, including the reliance on hospital-wide incidence data from the early 1990s and inclusion of larger hospitals that were not geographically representative. Without a source of surveillance data descriptive of HAI from all patient care areas, estimating the burden of HAIs will continue to be challenging. However, until surveillance reporting from across the spectrum of health care provision occurs, the results from national surveys may be used to estimate overall prevalence and provide a basis to develop national guidelines for HAI prevention [4–7].

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Reprints or correspondence: Dr. Eloisa Llata, Div. of Healthcare Quality and Promotion, Centers for Disease Control and Prevention, 1600 Clifton Rd. NE, Mailstop A-24, Atlanta, GA 30333 (ellata@cdc.gov).

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During the past 3 decades, prevalence surveys have been used as instruments to yield cost-effective alternatives to more resource-demanding prospective surveillance studies designed to evaluate the incidence and burden of HAIs [1, 4–33]. Although incidence data reflect the number of new people who become affected with a condition, prevalence data are an estimation of the burden of people who currently have a condition, so more HAIs are represented in the numerator (i.e., both new and already established infections). A point prevalence survey measures the proportion of patients infected with HAIs at the time the survey is conducted, usually during 1 day. Prevalence measures are more likely to capture HAIs of longer duration and patients with longer lengths of stay (e.g., more comorbidities). Despite the limitations, this surveillance method offers the advantages of being relatively inexpensive and time limited. Surveys performed at periodic intervals can provide useful comparative data, allowing identification of trends in infection and evaluation of infection control interventions [5, 12, 14, 26, 31, 32]. Some authors have attempted to estimate the cumulative incidence of HAI from prevalence studies with mixed results [34–36]. However, routine applicability of such extrapolations have not been used. The additional information needed to calculate incidence adds to the burden of data collection; parsimonious collection is a key contributor to the successful conduct of a voluntary prevalence survey.

Although the literature is replete with examples of national prevalence surveys performed in other countries, many studies used different study designs, making it difficult to compare prevalence rates among them. Important factors that influence the design of a prevalence study include the selection of the facilities and patients surveyed, the qualification and training of investigators, and the methods applied to the classification of HAIs. We systematically reviewed the English-language literature on prevalence surveys published from 1996 through 2008. We searched the Ovid Medline electronic database by using Boolean terms with the keywords “point prevalence surveys,” “nosocomial infections,” “healthcare-associated infections,” “hospital acquired infections,” and “prevalence study.” We also manually searched the bibliographies of all relevant reviews and primary studies to identify cited articles that were not captured by electronic searches.

**SELECTION OF REPORTING FACILITIES**

The prevalence surveys conducted outside the United States in the past 11 years reveal wide variation in the overall HAI prevalence rates, from 3.5% to 19.1% [4–33, 37] (table 1). Variability in study design and execution accounts for much of the difference in the estimated rates. In most cases, hospital selection was voluntary and was not representative of the country’s over-all hospital system. In general, large public teaching hospitals tended to participate, and several countries selected only 1 main tertiary care referral center as a surrogate to estimate the magnitude of HAI in those hospitals. In 1 survey, researchers reported that facilities declined to participate because of increased workload, limited resources to complete the survey, and fear that the survey represented a form of external quality control [5]. For results of a prevalence survey to be meaningful on a national level, it is important to develop a sampling scheme that can yield representative data on all hospitals in the country.

Studies also varied in the ward and patient groups surveyed. Several studies evaluated only medical, surgical, and critical care units where patients are at highest risk for HAIs [7, 13, 16, 26, 28]. The inclusion of areas with patients at lower risk for HAI would produce a lower prevalence rate, as was seen in studies from Norway and Germany [5, 16]. However, a French survey included non–acute care areas, such as long-term care and rehabilitation wards, and described high prevalence rates of 7.6% and 9.3%, respectively, among patients in these settings [4].

**TRAINING AND BACKGROUND OF DATA COLLECTORS**

Determining whether patients have HAIs requires considerable training so that standard definitions for infection can be applied at all facilities participating in a prevalence survey. Differences in background and training of data collectors are sources of considerable variation in methods among published studies. The SENIC project addressed this issue by requiring extensive training of all data collectors. The same group of investigators visited each of the 338 hospitals and reviewed patient records for determination of HAIs. Although costly, this approach enabled consistent application of HAI definitions and an appreciation of the survey process by the data collectors. Few other studies used the same group of investigators at multiple hospitals. In the study by Gastmeier et al. [16], surveillance was conducted by 4 physician investigators who traveled to 72 selected German hospitals. Because a validation study was not practical at each of the facilities, they focused on ensuring high interrater reliability (IRR) by using designated investigators. The investigators attended joint training sessions and validated HAI determinations before the survey by reviewing a subset of cases that were measured against a “gold standard” established by 2 of the study supervisors. This aspect of the study design was considered critical, because the authors recognized that the criteria for the diagnosis of HAI are complex and not easy to apply without properly trained investigators. Most of the other prevalence studies were performed by the staff at local hospitals, usually infection preventionists who had training and expertise in monitoring patients with HAIs. Other surveys used personnel with less training in infection control, such as nurses [4, 5, 13], pharmacists [8], or medical students [11]. The sensitivity
Table 1. Survey characteristics in recent published national prevalence surveys, 1996–2008.

<table>
<thead>
<tr>
<th>Country [reference]</th>
<th>Prevalence, %</th>
<th>No. of hospitals</th>
<th>Population study size</th>
<th>Age of participants, years</th>
<th>Wards</th>
<th>Evaluation study</th>
<th>Infection types</th>
<th>Modifications of CDC definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania [13]</td>
<td>19.1</td>
<td>1</td>
<td>968</td>
<td>&gt;1</td>
<td>M, S, I</td>
<td>IRR</td>
<td>LRTI, SSI, UTI, BSI, gastrointestinal, skin or burn</td>
<td>Skin or burn infection</td>
</tr>
<tr>
<td>Canada [17]</td>
<td>9.1</td>
<td>19</td>
<td>997</td>
<td>0–18</td>
<td>All</td>
<td>None</td>
<td>Pneumonia, SSI, UTI, BSI, CDAD, NE, UGI, URI</td>
<td>CVC–associated BSI definition</td>
</tr>
<tr>
<td>Canada [18]</td>
<td>10.5</td>
<td>25</td>
<td>5750</td>
<td>&gt;19</td>
<td>All</td>
<td>None</td>
<td>LRTI, SSI, UTI, BSI, and CDAD</td>
<td>CVC–associated BSI</td>
</tr>
<tr>
<td>Finland [25]</td>
<td>8.5</td>
<td>30</td>
<td>8234</td>
<td>&gt;5</td>
<td>All</td>
<td>None</td>
<td>Pneumonia, SSI, UTI, BSI</td>
<td>Clinical sepsis</td>
</tr>
<tr>
<td>France [4]</td>
<td>7.6</td>
<td>830</td>
<td>263,334</td>
<td>All</td>
<td>All</td>
<td>None</td>
<td>All</td>
<td>UTI, LRTI, bacteremia, catheter-related infection definitions</td>
</tr>
<tr>
<td>Germany [16]</td>
<td>3.5</td>
<td>72</td>
<td>14,996</td>
<td>All</td>
<td>M, S, I</td>
<td>IRR</td>
<td>LRTI, SSI, UTI, BSI, and other</td>
<td>None</td>
</tr>
<tr>
<td>Greece [6]</td>
<td>9.3</td>
<td>14</td>
<td>3925</td>
<td>All</td>
<td>M, S, P, I</td>
<td>None</td>
<td>LRTI, SSI, UTI, BSI, and other</td>
<td>None</td>
</tr>
<tr>
<td>Hong Kong [23]</td>
<td>4</td>
<td>1</td>
<td>1021</td>
<td>All</td>
<td>All</td>
<td>None</td>
<td>Pneumonia, SSI, UTI, BSI</td>
<td>None</td>
</tr>
<tr>
<td>Indonesia [11]</td>
<td>5.9</td>
<td>2</td>
<td>2232</td>
<td>All</td>
<td>M, S, P, I</td>
<td>IRR</td>
<td>UTI, SSI, sepsisemia, and phlebitis</td>
<td>Added phlebitis</td>
</tr>
<tr>
<td>Iran [22]</td>
<td>8.8</td>
<td>8</td>
<td>2667</td>
<td>All</td>
<td>M, S, P, I</td>
<td>None</td>
<td>SSI, UTI, BSI</td>
<td>None</td>
</tr>
<tr>
<td>Italy [33]</td>
<td>7.8</td>
<td>59</td>
<td>9467</td>
<td>&gt;1</td>
<td>All</td>
<td>None</td>
<td>LRTI, SSI, UTI, BSI, UTI-ASB</td>
<td>None</td>
</tr>
<tr>
<td>Lebanon [8]</td>
<td>6.8</td>
<td>14</td>
<td>834</td>
<td>All</td>
<td>All</td>
<td>None</td>
<td>LRTI, SSI, UTI, BSI, and phlebitis</td>
<td>None</td>
</tr>
<tr>
<td>Lombardy [24]</td>
<td>4.9</td>
<td>88</td>
<td>18,667</td>
<td>All</td>
<td>All</td>
<td>None</td>
<td>LRTI, SSI, UTI, BSI, and GI</td>
<td>Modified BSI</td>
</tr>
<tr>
<td>Russia [19]</td>
<td>17</td>
<td>1</td>
<td>472</td>
<td>&lt;18</td>
<td>All</td>
<td>IRR</td>
<td>LRTI, SSI, UTI, BSI</td>
<td>None</td>
</tr>
<tr>
<td>Scotland [37]#</td>
<td>9.5</td>
<td>45</td>
<td>13,754</td>
<td>&gt;16</td>
<td>All</td>
<td>IRR</td>
<td>All</td>
<td>None</td>
</tr>
<tr>
<td>Slovenia [7]</td>
<td>4.6</td>
<td>19</td>
<td>6695</td>
<td>All</td>
<td>M, S, I</td>
<td>None</td>
<td>All</td>
<td>None</td>
</tr>
<tr>
<td>Switzerland [28]</td>
<td>13</td>
<td>4</td>
<td>1349</td>
<td>&gt;16</td>
<td>M, S, I</td>
<td>V</td>
<td>Pneumonia, SSI, UTI, BSI</td>
<td>Eliminated ASB</td>
</tr>
<tr>
<td>Thailand [9]</td>
<td>6.8</td>
<td>20</td>
<td>9865</td>
<td>All</td>
<td>All</td>
<td>None</td>
<td>LRTI, SSI, UTI, BSI, GI, skin and soft tissue, and other</td>
<td>None</td>
</tr>
<tr>
<td>Turkey [26]</td>
<td>13.4, 10.9</td>
<td>1</td>
<td>307</td>
<td>All</td>
<td>M, S, I</td>
<td>None</td>
<td>Pneumonia, SSI, UTI, BSI</td>
<td>None</td>
</tr>
<tr>
<td>United Kingdom/ Ireland [31]</td>
<td>7.6</td>
<td>270</td>
<td>75,694</td>
<td>&gt;11</td>
<td>All</td>
<td>IRR</td>
<td>All</td>
<td>None</td>
</tr>
</tbody>
</table>

NOTE. ASB, asymptomatic bacteruria; BSI, bloodstream infection; CDAD, Clostridium difficile–associated disease; CDC, Centers for Disease Control and Prevention; CVC, central venous catheter; GI, gastrointestinal; I, intensive care unit; IRR, interrater reliability; LRTI, lower respiratory tract infection; M, medical; NE, necrotizing enterocolitis; P, pediatrics; S, surgical; SSI, surgical site infection; UGI, upper gastrointestinal tract infection; URI, upper respiratory tract infection; UTI, urinary tract infection; V, validation.

# Hospital selection included both acute care hospitals (100%) and non–acute care hospitals (25%).

of the diagnosis of an HAI is markedly influenced by the experience of the surveyors; inclusion of infection preventionists among the data collection teams has been reported to improve accuracy [38].

Investigator training for most surveys consisted of review of the protocol and case definitions and instruction on the use of the standardized algorithms for case finding. Training materials often included a collection of complex case studies, training manuals, and database programs. In some cases, trained regional coordinators organized training sessions for the local staff, as was performed in a 2006 survey across England, Wales, Northern Ireland, and the Republic of Ireland [37]. The authors credited the success of the survey on the training that the coordinators and participating hospital staff received, providing a sound framework for the survey to be conducted in a consistent and correct manner.

Credibility in the findings of previous surveys has been increased by the use of IRR studies to evaluate the frequency of discrepant results and consistency of case identification among data collectors. The Scotland study ensured reliable and valid
data collection by using a crossover design, in which data collectors were divided into 2 teams and surveyed a subset of inpatients. Although some inconsistencies were noted related to antimicrobial and invasive device use, most of the data examined revealed a high level of agreement [37]. In the German study, investigators evaluated IRR using a collection of case studies and estimated their case-finding approach to have a sensitivity of 95.6% and a specificity of 92.8% [16]. The authors suggested that the high specificity of the surveyors was one of the main reasons for the overall low prevalence rate, compared with other national prevalence studies. The Smyth et al. [31] study also conducted a study for IRR variation between the hospital staff and expert study personnel who had received intensive training. The validation study was conducted on the same day as the prevalence survey. The validation assessment was used to produce adjusted estimates of prevalence, accounting for differences in case ascertainment between local staff and expert study personnel. Overall, less than one-half of the prevalence surveys included an evaluation of the data (table 1). Of those that included either a validation or an IRR study, the results were varied, underscoring the need for a formal evaluation to add confidence to the interpretation of the data.

IDENTIFICATION OF HAI

Many methodological factors may influence the identification of HAI. The definitions should be simple, unambiguous, and easy to apply consistently by different observers. In most prevalence surveys, definitions of infection were based on CDC definitions [39] to classify infections. Decisions to use modified definitions were due to local differences in data availability rather than difficulty in applying the CDC definitions. For example, several studies did not include asymptomatic bacteriuria as a criterion because of the diminished availability of microbiology reports [5, 23, 28, 32]. Other studies did not evaluate all infection sites. Some studies monitored the most common infection sites and additional infections, such as phlebitis [11], gastrointestinal infections [8, 13], and skin or burn infections [13].

Different sites were found in the health care records used in the surveys. In many instances, the observers used existing documentation, including the medical record, available laboratory data, nurses’ records, radiology reports, consultation with ward staff members, and (in some cases) direct observation of the patient. However, the sources varied widely across all prevalence surveys. For example, microbiology reports were the primary data source for detection of urinary tract infections and bloodstream infections in several surveys [6, 7, 16, 19].

However, in hospitals where these resources were not as readily available or in situations in which empirical therapy was frequently administered without first obtaining a diagnostic culture, the prevalence survey results likely underestimated true prevalence. In Germany, only 14 of the 72 hospitals had an on-site microbiology laboratory, and those hospitals reported higher frequencies for almost every type of HAI, compared with hospitals that did not have in-house laboratory services [16]. Thus, use of definitions in which microbiology results are required is likely to underestimate the true prevalence of HAI (i.e., HAI without microbiology confirmation will not be captured using these definitions).

Another variation in case-finding approaches is the use of screening criteria. One of the more challenging components of conducting a prevalence survey is the detection of infections using a screening algorithm, such as a single patient characteristic (or a combination of patient characteristics), to increase the efficiency of case finding. Brusaferro et al. [40] evaluated a screening system designed to reduce the number of data sources needed and the number of patients who needed to be evaluated in detail for an HAI. This screening system reduced the time required for case finding by evaluating only those patients with indicators that correlated with the presence of the most common HAI (e.g., bloodstream, surgical site, lower respiratory tract, and urinary tract infections). All HAI (sensitivity, 100%) were detected when all 3 indicators (i.e., temperature >38°C, antibiotic receipt, and presence of an invasive device) were present on the day of assessment, requiring surveillance of only 62% of patients. A combination of any 2 indicators yielded a sensitivity of 98%. Use of the presence of fever and devices as screening criteria reduced the number of patients who needed to be fully evaluated to 41% while maintaining 98% sensitivity to detect all HAI. Among patients who were fully evaluated, a mean of 9 min per patient was required to consult all available data sources and assess a patient for an HAI. By using this screening system, the time invested averaged 4 min per patient in the survey. An Indonesian study used different indicators (i.e., surgical operations and use of urinary catheters or intravenous catheters) and found that 90% of the HAI would have been detected while evaluating only 60% of the hospitalized patients [11]. Gastmeier et al. [41] determined that the presence of both a positive microbiology culture result and current antimicrobial therapy detected 75% of the prevalent HAI by reviewing only 20% of patient records. Although the best HAI indicators in terms of sensitivity and specificity have not been established for US prevalence surveys, HAI indicators can reduce the number of patients who require a full evaluation and make implementation of US prevalence surveys more feasible.

UTILITY OF PREVALENCE SURVEYS

Despite apparent disagreement on a standardized method, prevalence surveys have provided insight into the burden of HAI for many countries during the past several decades [6, 7, 9–14, 16–25, 27–33, 37]. For countries such as Turkey and Lebanon, participating in the surveys meant obtaining their
Table 2. Design challenges in a national prevalence survey study for the United States.

<table>
<thead>
<tr>
<th>Design component</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities selection</td>
<td>Efforts should concentrate on developing a sampling strategy scheme to select hospitals that yield data representative of entire United States.</td>
</tr>
<tr>
<td>Ward selection</td>
<td>Case mix is determined by what wards are surveyed. To have meaningful results, ward selection should include both high-risk and low-risk areas of the hospital.</td>
</tr>
<tr>
<td>Investigators</td>
<td>The success of a national survey will largely rely on voluntary participation of infection control professionals knowledgeable in the application of definitions of HAI. Some training is necessary to ensure valid aggregation of the data.</td>
</tr>
<tr>
<td>Data collection</td>
<td>Data collection depends on purpose and practicality. Being parsimonious with data will help determine national estimates of HAIs and will contribute to the feasibility of the survey.</td>
</tr>
<tr>
<td>Infection sites</td>
<td>Most published surveys chose to record selected sites, but for more comprehensive data, all infection sites should be evaluated to ensure a comprehensive assessment.</td>
</tr>
<tr>
<td>Evaluation studies</td>
<td>Although few published surveys performed validation or interrater reliability studies, they can add confidence to the interpretation of the data and reliability to the national estimates and interpretation.</td>
</tr>
</tbody>
</table>

**NOTE.** HAI, health care–associated infection.

first burden estimates of HAIs, contributing to awareness, motivation, and general improvement in HAI surveillance methods. The prevalence survey in Scotland incorporated a separate burden study to document health service use and costs to guide future national policy priorities. Findings from the French survey in 1996 influenced the decision to launch a program to reduce the incidence of HAIs by 30% during a 5-year period. In countries that have repeated prevalence surveys, findings have formed the basis for design of infection control policies and provided a way to evaluate the effectiveness of infection control measures [5, 12, 14, 26, 31, 32]. Weinstein et al. [42] reported on a decade of prevalence surveys in a tertiary care center and found them to be useful in following trends and rates of infection and device use. Norway used the results of its survey in 2003 to rank hospital quality for comparisons among hospitals. However, many of these hospitals perceived the process to have misclassified their facility as a hospital with an infection problem [5]. Care must be taken not to relate prevalence data between individual facilities as a measure of quality of care; calculations of a prevalence rate from a point prevalence survey lack precision at the individual hospital level because the rate usually combines HAIs at all sites in the numerator and is not a risk-adjusted measure for comparison among hospitals [43].

**FUTURE DIRECTIONS**

There are several evolving aspects of HAI detection and reporting that have the potential to augment burden estimates. Recent trends of state-mandated HAI reporting are changing the current landscape of HAI surveillance in the United States. If this trend continues nationally, HAI surveillance efforts will produce robust estimates of disease but potentially with a narrow focus. For example, many mandates include central line–associated bloodstream or surgical site infections, but other sites of HAI are not included. In addition, shifts in the case-finding methods from manual assessments to automated detection through the use of capturing electronic data elements may facilitate hospital-wide surveillance of the major types of HAIs; however, some HAI types will not be identified using these methods.

Currently, HAI case-finding efforts in the United States do not enumerate all cases needed to describe the full spectrum of HAIs. A national prevalence survey represents an efficient and potentially more accurate method to make estimates in the immediate future. Examples of meaningful regional and national assessments of the burdens of HAIs have been produced by prevalence surveys [1, 4–8, 12, 16–18, 28, 31, 32, 37]. Such information can be used to prioritize resources and to inform stakeholders in the continuing effort to reduce HAIs. A recent 2005 point prevalence survey of nursing home–associated infections was conducted in the United States by the Veteran’s Administration Nursing Home Infection Surveillance Task Force [44]. This survey demonstrated that point prevalence surveys can be feasible if they use uniform definitions and establish the necessary infrastructure to conduct the surveys. Experience gained from these and other studies emphasized the importance of representative data, well-trained HAI case finders, IRR exercises, and uniformity of HAI definitions (table 2).

As health care delivery changes, along with changes in devices and procedures, emerging infection will inevitably occur. A national measure of HAI burden describing the full spectrum of HAIs would help efforts to guide interventions to reduce...
HAIs and identify areas that require further focused surveillance efforts. Although challenges exist, a national US prevalence survey is an efficient method to measure and report on the spectrum of HAIs from a national perspective that should be considered. In the United States, development of a survey based on facility staff and primary surveyors similar to the Smyth et al. [31] model could be achieved by using a representative sample of facilities within or external to the National Healthcare Safety Network. Facility and patient selection, as well as infection preventionist training, for a national prevalence survey will require considerable effort. However, evidence from prevalence surveys in other countries demonstrates that it can be done.

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**References**