

# Cost of hospital-associated infections in Massachusetts

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The Massachusetts Department of Public Health appointed an Expert Panel to assess the problem of health care-associated infections (HAI) in the state and make recommendations regarding mandatory reporting. At the Expert Panel's request, a cost-of-illness study was conducted using available data sources. In Massachusetts, the excess hospital costs attributed to HAIs were estimated at approximately \$233 to \$275 million in 2006. (Am J Infect Control 2008;■■■■■■■■)

Health care-associated infections (HAIs) are a major patient safety problem, frequently associated with surgical sites and invasive devices, such as vascular access lines, urinary catheters, and ventilators.<sup>1,2</sup> The hospital-related financial burden of HAIs in the United States was estimated to exceed \$4.5 billion in 1992.<sup>3</sup> Using the Consumer Price Index (CPI), this converts to \$6.65 billion in 2007 dollars. This estimate is based on infection rates and associated costs from the mid-1970s, however.<sup>4</sup> Health care delivery has undergone many changes over the past 30 years, and today patients are at increased risk for HAIs caused by drug-resistant organisms, which is likely to increase patient morbidity and mortality as well as costs.<sup>5-7</sup>

In an effort to promote effective prevention strategies in hospitals and provide quality information to consumers, many states have legislated hospital reporting of select HAIs to health authorities and/or the public. In Massachusetts, the Department of Public Health (DPH) has been charged with developing a statewide infection prevention and control program. To assess the problem of HAIs and make recommendations regarding mandatory reporting to the DPH, an interdisciplinary Expert Panel was convened by the Betsy Lehman Center for Patient Safety and Medical Error Reduction. This study was part of a comprehensive assessment of the problem of HAIs in the state, conducted at the request of the Expert Panel. Specifically, the purpose of this study was to estimate the economic burden of HAIs in

acute care nonfederal hospitals in Massachusetts for the year 2006. The Expert Panel was interested in the excess costs attributable to surgical site infections (SSIs), bloodstream infections (BSIs), and ventilator-associated pneumonia (VAP). Urinary tract infections (UTIs) also were included, because they have been identified as the most frequent type of HAI.<sup>8</sup>

## METHODS

A cost-of-illness study was conducted, and data on both the excess costs attributable to each type of infection and the frequency of occurrence were obtained. Optimally, these data come directly from the hospitals of interest, with cases and controls identified using standard definitions and protocols, such as those developed by the Centers for Disease Control and Prevention (CDC) and used in the National Healthcare Safety Network (NHSN).<sup>9</sup> The only state-specific data available were related to the annual number of hospital discharges, however. These aggregate data were provided by the Massachusetts DPH. Data on HAI incident rates and the associated excess costs attributable to HAIs in the Massachusetts were not available; thus, other data sources were needed. Specifically, 2 distinct data sources, each with its own strengths and weaknesses, were available to the study team, and the cost of HAIs to the state was computed separately from each data source. For each data source, a base-case analysis and a sensitivity analysis were conducted. In the base-case analysis, the best estimates for each input were computed. Sensitivity analyses were then conducted to explore the impact of assumptions in the data.

The first data source was published literature, which has been recommended when site-specific data are unavailable.<sup>10</sup> To estimate the incidence of HAIs, published estimates of the overall incidence of the various types of HAIs extrapolated from the NHSN data were used. Researchers from the CDC recently published data on the overall rate of HAIs per 100 hospital admissions and estimated the proportion of SSIs, BSIs, VAP, UTIs,

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and other infections in US hospitals.<sup>8</sup> Using these published data and the annual number of hospital discharges in Massachusetts in 2006, the incidence of the various types of HAIs was estimated.

To estimate the costs associated with each type of HAI, we updated previous published systematic reviews of the literature.<sup>11,12</sup> Data from original studies were examined if the report was published between January 1995 and December 2006, had an abstract for review, contained an original excess cost estimate attributable to the HAI of interest, and was written in English. Methodologic articles and editorials were excluded. To find the published analyses, searches were conducted in MEDLINE, EconoLit, and HealthSTAR using the medical subject headings or text keywords for each infection type cross-referenced with “costs,” “cost analysis,” “economics,” or “cost-effectiveness analysis.” In addition, review articles were examined for published articles that met the inclusion criteria, and other published articles known to us also were included.

Important concepts to consider when determining the excess costs attributable to HAIs are adjustment for patients’ underlying severity of illness, comorbid conditions, and length of hospital stay before acquiring the infection. Failure to consider and adjust for these factors can result in biased estimates of attributable costs, usually making the infection seem more expensive. Therefore, we used only data from published articles that controlled for confounding in some method (eg, patient risk for infection).

All published cost estimates were inflation-adjusted to 2006 US dollars using the medical care services component of the non-seasonally adjusted CPI. Any non-US currencies were converted to US dollar amounts using the Economic Research Federal Reserve Bank of St. Louis FRED II (<http://research.stlouisfed.org/fred2/categories/15>), based on the rate from January 1 of the year of the study data. Because of the known variation in cost estimates and lack of normal distribution, and to be conservative, the medians were used to estimate attributable costs for each infection type in the base-case analysis. In sensitivity analysis, the costs were varied using the means calculated from the published point estimates.

A second data source was made available to the research team: aggregate reports from an electronic data mining system that links hospital financial data with clinical laboratory data and identifies incidence and incremental costs of HAIs using nosocomial infection markers (NIMs). In this system, the NIMs are classified as urinary, blood, respiratory, wound, stool and other. The NIMs provide electronic, laboratory-based markers for HAIs that have hospital-wide case finding with reported sensitivity of 0.86 and specificity of 0.98.<sup>15</sup> In addition, postdischarge cultures are captured.

Aggregated data were available from 2 nonexclusive samples. The first sample was approximately 1.9 million admissions from 83 hospitals nationwide (personal communication, Sean Tinney, Medmined, March 9, 2007). Data also were available from a smaller subset of hospitals specific to the northeast US region, which included 331,000 admissions from 18 hospitals. For both samples, aggregated data on the incidence of the various types of NIMs were available. Similar to the method used in the published data, the overall incidences of the infections in Massachusetts were extrapolated based on the annual number of hospital discharges for 2006.

The electronic system computes an incremental cost by comparing the financial records of those patients identified with an NIM with the records of those patients without an NIM. In this electronic system, severity of illness is controlled for by stratifying patients by diagnosis-related groups and computing the average incremental cost for those with an NIM compared with that for those without an NIM. These proprietary summary data were from multiple years, and it was not possible to inflate the cost data into a consistent year currency. In the national data set, the numbers of each NIM type and the associated incremental costs were available, as was a “total cost of all infections.” The northeast data set included the number of each NIM type; however, cost data were available only for the “total cost of all infections” estimate, which was 4.3% higher per infection than the national estimate. In the base case, the incremental cost of each NIM type was inflated by 4.3%, which was then multiplied by the frequency data of each NIM type from the northeast data set. The national estimates of NIM rates and noninflated costs were used in the sensitivity analysis.

## RESULTS

A total of 752,126 discharges were recorded in Massachusetts in 2006. Table 1 gives the data used in the first method of estimating the excess cost of HAIs, based on the CDC-estimated overall HAI rate of 4.5%.<sup>8</sup> To estimate the cost attributable to these infections from the literature, more than 200 titles and manuscripts were audited. Eighteen studies met our inclusion criteria and were used in to estimate the cost of specific HAI types from the published literature.<sup>14-31</sup> The most common type of infection was UTIs, but the attributable cost per infection was the lowest for this type. SSIs were the second-most prevalent HAI and the most costly. In the base-case analysis, the attributable hospital costs of HAIs exceeded \$275 million. In the sensitivity analysis, this cost rose to \$473 million. In both the base-case and sensitivity analyses, the HAIs with the highest annual attributable

**Table 1.** Data for computations and estimate of excess costs attributed to HAI based on published literature

Infection type	Attributable costs		Data source
	Median	Mean	
VAP	17,904	23,818	14-18
BSI	15,153	19,192	19-21
SSI	11,710	25,546	22-29
UTI	1257	1257	30,31
Other	2990	9348	11,12
Percent and frequency			
	% of infections	n	
VAP	0.15	5077	8
BSI	0.14	4738	8
SSI	0.22	7446	8
UTI	0.32	10,381	8
Other	0.17	5754	8
Total	1.0	33,846	
Excess costs			
	Base case	Sensitivity analysis	
VAP	\$90,898,608	\$120,920,425	
BSI	\$71,800,881	\$90,939,254	
SSI	\$87,193,215	\$190,216,727	
UTI	\$8,707,814	\$18,520,351	
Other	\$17,203,359	\$53,786,185	
Total	\$275,436,966	\$473,554,399	

All cost data are presented in 2006 US dollars. Frequency of infections is based on the annual number of discharges from Massachusetts acute care hospitals in 2006 (n = 752,126).

costs were VAP, SSIs, and BSIs, although the rank order was not consistent.

Using the aggregate electronic data mining source, the overall NIM rate was 4.7% in the national sample and 5.7% in the northeast subset. Table 2 gives the data used in the second method of estimating the excess cost of HAIs, along with the results of this estimate. In these data, the wound and respiratory NIMs had a relatively low incidence rate of 0.11. The wound NIM also had the lowest incremental cost. The "other" category was the most frequent type of NIM. Based on these data, the increased annual hospital costs attributable to HAIs ranged from \$233 million in the base-case analysis to \$184 million in the sensitivity analysis.

## DISCUSSION

Using the annual number of hospital discharges and 2 separate data sources to estimate the incidence of HAIs and attributable costs, the extra hospital costs associated with HAIs in Massachusetts in 2006 ranged from approximately \$233 million to \$275 million in the base-case analysis. In the sensitivity analysis, the range of costs was even greater, from a low of \$184 million to a high of \$470 million annually. Although determining a specific point estimate of the costs of HAI is

**Table 2.** Incremental costs and rate of nosocomial infection markers (NIMs) from electronic data

Data	Base case	Sensitivity analysis	
Infection type	Incremental costs of NIM		
	Northeast	National	
Respiratory	\$8686	\$8328	
Blood	\$7854	\$7530	
Wound	\$3622	\$3473	
Urinary	\$4205	\$4032	
Stool	\$4697	\$4503	
Other	\$5215	\$5000	
Percent and frequency of NIMs			
	% of NIM	Northeast, n	National, n
Respiratory	0.11	4757	3913
Blood	0.12	5190	4269
Wound	0.11	4757	3913
Urinary	0.31	13,407	11,028
Stool	0.05	2,162	1,779
Other	0.30	12,974	10,673
Total	1.0	43,237	35,575
	Base case	Sensitivity analysis	
Respiratory	\$41,320,840	\$32,587,464	
Blood	\$40,757,915	\$32,145,570	
Wound	\$17,231,902	\$13,589,849	
Urinary	\$56,379,076	\$44,464,896	
Stool	\$10,155,649	\$8,010,837	
Other	\$67,659,221	\$53,365,000	
Total costs	\$233,504,602	\$184,163,616	

difficult, clearly the annual attributable costs of HAIs to the state are high.

The base case cost estimates are conservative and actually may underestimate the excess cost attributable to HAIs for the several reasons. All data were based on hospital costs only. There was no attempt to estimate the burden of infections associated with long-term care facilities, outpatient procedures, or federal hospitals, such as the Veterans Health Administration. Even in these acute care hospitals, the costs of interventions, such as the need for a private isolation room, increased clinician time, and isolation supplies (eg, gowns and gloves), are not captured.<sup>12</sup> Furthermore, a complete societal cost-of-illness analysis would include outpatient costs and any attributable long-term health consequences.<sup>32</sup> In addition, the electronic data available at the time of this analysis may underrepresent some of the hospital costs. Recently, another analysis of the NIM data has been published using 1.3 million patient admissions from 55 hospitals over a 5-year period.<sup>33</sup> In those data, 5 additional categories of NIMs were available to those researchers (ie, 1, cerebrospinal fluid; 2, eye; 3, ear, nose and throat; 4, gastrointestinal; and 5, abscess). Only 2.7% of the

NIMs were captured in the “other” category. In that report, the estimated costs of the additional categories ranged from \$31,573 per cerebrospinal fluid NIM to \$13,606 per gastrointestinal NIM. In the data reported here, the largest proportion of the NIMs was in the “other” category (30%), with incremental costs of about \$5,000. Therefore, this likely underestimates the actual costs of the “other” NIMs.

A key assumption in the first method of cost estimation is the published HAI rate of 4.5%. Although this assumption is based on the best data available from the CDC, it may not be accurate. If the infection rate were 3.5%, then the annual cost of HAIs would decrease to \$369 million. Although in the electronic data, the infection rate also was about 5%, giving more confidence in the published estimate, further research is warranted to establish actual HAI rates.

Pennsylvania provides state-level financial data related to HAIs through the website on the Pennsylvania Health Care Cost Containment Council website (<http://www.phcr.org>). In this state, the estimated additional insurance payments for HAIs in 2004 were \$613.7 million (<http://www.phc4.org/reports/researchbriefs/032906/nr032906.htm>). These reports have not been formally peer-reviewed, however, and they analyze insurance payment data (ie, charges), not attributable costs. To the best of our knowledge, this is the first peer-reviewed report to estimate the excess costs (not charges) attributable to HAIs at the state level.

Our estimation approach has both strengths and limitations. Strengths include the use of 2 distinct data sources, which provides a more complete picture of the potential incidence and excess costs attributable to HAIs, and the use of regional data (even though it is not precise). In addition, conducting a sensitivity analysis provides a more complete range of attributable costs. Other investigators have conducted sensitivity analyses to estimate the numbers of infections in patients in intensive care units versus those in patients not in intensive care units, as well as varying estimates based on distributions (eg, confidence intervals) and/or bootstrapping. Although these methods are appropriate for explanatory modeling of costs, they were not used in this cost-of-illness type study. Comparing the results from both data sources reveals distinct similarities and differences. Overall rates of HAIs and NIMs were similar, as were specific types (eg, VAP compared with respiratory, 0.15 vs 0.11; BSIs compared with blood, 0.14 vs 0.12; UTIs compared with urinary, 0.32 vs 0.31). There was little similarity in the costs attributed to each infection type, however. Furthermore, there were distinct differences in the frequency of SSIs compared with that of wound infections between data sets. In the recently published NIM analysis, wound NIMs represented 14.3% of all infections.<sup>35</sup>

An inherent limitation to any cost-of-illness study is the availability of precise data. In the electronic data mining system data, the NIMs are identified with administrative data, and although sensitivity and specificity information is published, the data lack clinical confirmation of infection; in addition, there is only limited control for severity of illness in the calculation of costs. Furthermore, the characteristics of the northeast region hospitals are not known; thus, the generalizability of the results cannot be evaluated. Strengths of this system include that it is the largest financial data set available addressing HAIs, and it includes outpatient cultures to identify infection markers. A limitation of both the published data and the electronic data is that costs related to infections caused by drug-resistant organisms were not examined separately. Because of the difficulty in accurately estimating the incidence of drug-resistant organisms and the inability to tease out the costs from the available data, specific estimates of multiple drug-resistant infections could not be made. Although there were undoubtedly drug-resistant infections in all samples from which the cost data were extracted, how the rates compare with those in Massachusetts is not known. Strengths of the cost estimates synthesized from the published literature include the identification of infections based on well-accepted methodologies and attempts to find adequate controls for comparisons. However, the incident rates of the HAIs from the published literature were based on the hospitals that contributed data to the CDC network in 2001. These hospitals were most likely overrepresentative of larger academic-affiliated institutions.<sup>54</sup>

This study was conducted in response to changes in Massachusetts' health care law and the possible requirement for hospitals to report HAI rates and infection prevention and control practices. Mandatory reporting is a potential tool for improving quality of care and can help consumers, insurers, and providers make decisions on where to seek or how to fund health care. Reduction of HAIs through mandatory reporting should result in societal cost savings. The actual effect of mandatory reporting on HAI rates remains unknown, however. In addition, increased hospitals costs related to reporting as well as increased DPH administrative costs related to the oversight should be anticipated. With limited resources and the potential benefits of public reporting yet to be established, there is a need to carefully balance the additional burden of reporting with current prevention efforts to obtain the optimum outcome—fewer infections.

Based on our findings, it is not possible to determine a precise estimate of the annual economic burden of HAIs in Massachusetts. These infections are clearly expensive, however, costing the state's health care industry at least \$230 and most likely much more. The

methods used in this study should be beneficial for other state DPHs as well.

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