Underresourced Hospital Infection Control and Prevention Programs: Penny Wise, Pound Foolish? •

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OBJECTIVES.   To estimate the cost of healthcare-associated infections (HAIs) in a network of 28 community hospitals and to compare this sum to the amount budgeted for infection control programs at each institution and for the entire network.

DESIGN.   We reviewed literature published since 1985 to estimate costs for specific HAIs. Using these estimates, we determined the costs attributable to specific HAIs in a network of 28 hospitals during a 1-year period (January 1 through December 31, 2004). Cost-saving models based on reductions in HAIs were calculated.

SETTING.   Twenty-eight community hospitals in the southeastern region of the United States.

RESULTS.   The weight-adjusted mean cost estimates for HAIs were $25,072 per episode of ventilator-associated pneumonia, $23,242 per nosocomial blood stream infection, $10,443 per surgical site infection, and $758 per catheter-associated urinary tract infection. The median annual cost of HAIs per hospital was $594,683 (interquartile range [IQR], $299,057-$1,287,499). The total annual cost of HAIs for the 28 hospitals was greater than $26 million. Hospitals budgeted a median of $129,000 (IQR, $92,500-$200,000) for infection control; the median annual cost of HAIs was 4.6 (IQR, 3.4-8.0) times the amount budgeted for infection control. An annual reduction in HAIs of 25% could save each hospital a median of $148,667 (IQR, $74,763-$296,861) and could save the group of hospitals more than $6.5 million.

CONCLUSIONS.   The economic cost of HAIs in our group of 28 study hospitals was enormous. In the modern age of infection control and patient safety, the cost-control ratio will become the key component of successful infection control programs.

Approximately 1 in every 20 hospitalized patients experiences 1 or more healthcare-associated infection (HAI),[1] leading to an estimated 2.1 million HAIs occurring annually in the United States.[2,3] It is well established that patients with HAI have higher mortality rates and longer hospitalization durations than patients who do not develop HAIs.[3]

HAIs directly threaten patient safety.[4,5] Thus, it is fitting that the Institute for Healthcare Improvement's 100,000 Lives Campaign has focused on 3 of 6 key quality improvement initiatives on processes geared toward the prevention of HAI.[6] Furthermore, accreditation organizations, such as the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), include the prevention of HAIs as a key component in their accreditation standards. The JCAHO also includes the prevention of HAIs as one of its recommended patient safety goals.[7] The JCAHO and the Institute for Healthcare Improvement have increased awareness of the problem of HAIs among hospital administrators and the general public, but insufficient attention has been given to the financial burden that HAIs impose on hospitals. Indeed, in our experience, the business case for preventing HAIs is rarely, until recently, at the forefront in the minds of hospital administrators.

Although the cost of HAIs is clearly high, the absolute financial burden of HAIs and the cost of individual HAIs have been difficult to determine. For example, some previous estimates of the cost of HAIs do not account for the fact that the costs vary for each type of specific HAI, each type of infecting microorganism, and each specific therapy provided; furthermore, these broad estimates do not take into consideration the fact that the underlying condition of each infected patient affects the duration, type, and cost of treatment that is given.[8,9] Finally, published studies that have examined the cost of individual HAIs have provided wide-ranging and confusing results.

Accurate estimates of costs of HAIs are important metrics for understanding the impact of hospital infection control (IC) programs and, perhaps more importantly, for understanding how costs for IC programs can yield measurable

dividends. Thus, the objectives of this study were to calculate weight-adjusted average costs for specific HAIs, using previously published matched cost analyses; to determine the annual costs attributable to specific HAIs in a network of hospitals of various sizes and types; and to compare the costs of HAIs to the amount budgeted for IC programs in a group of 28 hospitals.

METHODS

HAI-Specific Cost Estimates

In 1985, the federal government instituted a prospective payment system based on diagnosis-related groups (DRGs),[3] leading to a change in hospital reimbursement patterns. Thus, cost analyses published before 1985 are fundamentally different than analyses published after the institution of the DRG reimbursement program. We reviewed the literature published during 1985-2005 and selected reports that described costs specifically attributable to surgical site infection (SSI), healthcare-associated bloodstream infection (HA-BSI), ventilator-associated pneumonia (VAP), and/or catheter-associated urinary tract infection (CA-UTI). We first performed a keyword search of broad terms, including "cost," "economic analysis," "surgical site infection," "wound infection," "bloodstream infection," "bacteremia," "pneumonia," and "urinary tract infection." We then reviewed the cited references of studies initially identified using these keywords to identify studies that may have been missed by our initial search. Subsequently, we used the ISI Web of Science (available at: http://portal.isiknowledge.com) to perform a cited reference search of articles identified using the search strategy described herein. Ultimately, studies were included in this analysis if they determined costs attributable to specific HAIs by matching patients with HAIs with similar patients without HAIs. Matching criteria used in each study had to be explicitly stated. Charge data were provided from 2 studies[10,11]; these charges were converted to costs using a cost-to-charge ratio of 0.7.[12]

All monetary amounts were standardized to the value of US dollars in August 2005; adjustment for inflation was performed using information from the Bureau of Labor Statistics.[13] If a specific monetary unit (eg, 1996 US dollars) was described in the article, information from the Bureau of Labor Statistics was used to convert the monetary unit to 2005 US dollars. If the monetary unit was not available, the first day of the month on which the article was originally submitted for review was used as the date for conversion to 2005 US dollars. If these data were not available, the date of publication was used as the date for conversion to 2005 US dollars. Foreign currency was converted to US dollars using Federal Reserve economic data.[14] After costs were standardized to 2005 US dollars, weight-adjusted mean costs were computed for SSI, HA-BSI, VAP, and CA-UTI by averaging weighted mean costs based on patient count from each study.

Participating Hospitals and Data Collection

The Duke Infection Control Outreach Network (DICON) is a network of 32 community-based hospitals in the southeastern region of the United States. The structure and goal of DICON have been previously described.[15] A total of 28 hospitals with 30-616 beds participated in surveillance activities for HAIs in DICON during 2004.

Data included in this study were prospectively collected at all 28 study hospitals from January 1 through December 31, 2004. Data collected included numbers of SSIs, HA-BSIs, VAP cases, CA-UTIs, patient-days, exposure-days, and surgical procedures. Data concerning HAIs were identified by local IC personnel by use of standardized methods and Centers for Disease Control and Prevention definitions for HAIs.[16] One hospital did not perform surveillance on catheter-days or CA-UTIs; thus, data on CA-UTIs were available for 27 hospitals. Similarly, data on SSIs were available from 27 hospitals, because no surgical procedures were performed at 1 hospital. Surveillance for superficial SSIs was not performed; thus, only deep or incisional and organ space SSIs were included in this analysis. Estimates for the cost of specific HAIs were applied to the number of HAIs at each institution in 2004.

IC Budget Data

Surveys were sent to a total of 50 supervisory IC professionals (ICPs) at the 28 hospitals in this survey and were completed in December 2005. These surveys included a request for the annual hospital budget for the IC program at each hospital. Budgeted amounts were standardized to 2005 US dollars.

Cost Reduction Modeling

Models for both relative and absolute cost reduction scenarios were calculated. For absolute cost reduction models, a fixed number of HAIs (eg, 4) was subtracted from the total number of HAIs at each hospital. For relative cost reduction models, a fixed percentage of HAIs (eg, 25%) was subtracted from the total number of HAIs at each hospital. For each scenario, the total cost of HAIs was calculated using the equations described herein. The median cost reduction per hospital and total cost reduction for the 30 study hospitals were then calculated for each scenario.

Statistical Analysis

Data were maintained using Access (Microsoft) and analyzed using SAS statistical software, version 9.1 (SAS Institute). The Wilcoxon rank sum test was used to test differences between median values.

RESULTS

Estimates for Cost of Specific HAIs

Twenty-six studies published during 1985-2005 met all the inclusion criteria: 8 provided cost estimates for SSI,[17-24] 6 for

VAP,[10,11,25-28] 5 for nosocomial HA-BSI,[29-33] and 2 for CA-UTI.[19,34] One study provided cost estimates for 2 types of HAI.[19] Cost estimates provided in these studies were adjusted to 2005 US dollars. The weight-adjusted mean cost estimates were $25,072 per VAP case, $23,242 per HA-BSI, $10,443 per SSI, and $758 per CA-UTI (Table 1).

Study Hospital Surveillance Data

During 2004, surveillance for HAIs was performed on 1,430,048 patient-days, 132,050 surgical procedures, 62,960 urinary catheter–days, and 32,309 ventilator-days (Table 2). Data from the 28 hospitals represent information obtained from a total daily census of 4,358 beds, a median census per hospital-day of 110 patients (interquartile range [IQR], 75-224.5), and 46 intensive care units.

Number and Cost of Specific HAIs

During 2004, a total of 516 HA-BSIs were reported at the 28 study hospitals (overall rate for network, 0.36 HA-BSIs per 1,000 patient-days). The median number of HA-BSIs per study hospital was 7.5 (IQR, 4.5-26.5 HA-BSIs). Based on an estimated cost per HA-BSI of $23,242, the cost attributable to HA-BSI at the 28 study hospitals was $11,992,645. The median annual cost for HA-BSI per hospital was $174,315 (IQR, $104,589-$615,913).

A total of 1,075 SSIs were diagnosed at 27 study hospitals (overall rate for network, 0.81 SSI per 100 procedures). The median number of SSIs per study hospital was 30 (IQR, 13-61 SSIs). Based on an estimated cost per SSI of $10,443, the cost attributable to SSI at the study hospitals was $11,226,171. The median annual cost for SSIs per hospital was $313,290 (IQR, $135,759-$637,023).

A total of 257 CA-UTIs were diagnosed at 27 study hospitals (overall rate for network, 4.1 CA-UTIs per 1,000 catheter-days). The median number of CA-UTIs per study hospital was 4 (IQR, 2-19 CA-UTIs). Based on an estimated cost per CA-UTI of $758, the cost attributable to CA-UTI at the study hospitals was $194,780. The median annual cost for CA-UTIs per hospital was $3,032 (IQR, $1,516-$14,402).

A total of 109 VAP cases were diagnosed at 28 study hospitals (overall rate for network, 3.4 VAP cases per 1,000 ventilator-days). The median number of VAP cases per study hospital was 2 (IQR, 0-4 VAP cases). Based on an estimated cost per VAP case of $25,072, the cost attributable to VAP at the study hospitals was $2,732,853. The median annual cost for VAP per hospital was $50,144 (IQR, $0-$100,288).

By summing the annual costs for these 4 specific HAIs, the total annual cost attributable to HAIs was calculated to be $26,146,450 for the 28 hospitals (Table 3). The median total annual cost of HAIs per hospital was $594,683 (IQR, $299,057-$1,187,499). The median cost of HAIs per patient-day was $13.65 (IQR, $11.82-$24.30) for each hospital.

The total annual cost per hospital varied according to the size of the hospital. Of note, the 14 hospitals with fewer than 220 beds (median, 131 beds [IQR, 110-182 beds]) had a median total annual cost of HAIs of $299,057 (IQR, $198,416-$440,697), whereas the 14 hospitals with 220 or more beds (median, 353 beds [IQR, 294-400 beds]) had a medial total annual cost of HAIs of $1,187,499 (IQR, $902,280-$1,776,934) ($P < .001$). This difference, however, disappeared after adjusting for patient-days. The median cost of HAIs per patient-day for hospitals with fewer than 220 beds was $12.53 (IQR, $11.01–$15.68), whereas the median cost of HAIs per patient-day for hospitals with 220 or more beds was $14.88 (IQR, $12.32-$24.80) ($P = .43$).

IC Budget and Cost of HAIs

IC budget information was available from 17 hospitals. Nine hospitals (53%) had money budgeted specifically for IC, 5 hospitals (29%) had money budgeted for IC in conjunction with another department (eg, employee health or safety), and 3 (18%) had money budgeted for IC as part of a larger hospital component (1 with patient care, 1 with nursing care, and 1 with quality).

A total of $3,226,555 was budgeted for IC at these 17 hospitals in 2004. In total, HAIs cost $17,621,168 at these 17 hospitals during 2004. Thus, the total cost of HAIs at these 17 hospitals was 5.5 times the amount budgeted for IC. The median amount budgeted for IC per hospital was $129,163 (IQR, $92,500-$200,000) and $3.52 (IQR, $2.25-$6.47) per patient-day.

Hospitals employed a median of 1 ICP (IQR, 1-1.5). The median amount budgeted at each hospital for payment of ICPs was $65,750 (IQR $53,999-$89,365) or $1.75 (IQR, $1.35-$2.45) per patient-day. Twenty-four ICPs worked at these 17 hospitals. The median salary of these ICPs was

TABLE 1. Cost Estimates for Specific Healthcare-Associated Infections (HAIs)

HAI type	Weight-adjusted cost per HAI, mean ± SE	Range of published estimates of cost per HAI
Ventilator-associated pneumonia[10,11,25-28]	25,072 ± 4,132	8,682-31,316
Healthcare-associated bloodstream infection[29-33]	23,242 ± 5,184	6,908-37,260
Surgical site infection[17-24]	10,443 ± 3,249	2,527-29,367
Catheter-associated urinary tract infection[19,34]	758 ± 41	728-810

NOTE. HAIs are defined on the basis of Centers for Disease Control and Prevention criteria.[16] Data are in 2005 US dollars.

TABLE 2. Surveillance Data for Study Hospitals During 2004

Hospital data	Total no.	No. per hospital, median (IQR)
Daily census	4,358	110 (75-224.5)
No. of beds	7,082	219 (131-352.5)
No. of intensive care units	46	1 (1-2)
No. of patient-days	1,430,048	38,292.5 (23,497.5-72,852.5)
No. of surgical procedures	132,050	3,635 (1,813-5,626)
No. of ventilator-days	32,309	684.5 (442.5-1,670.5)
No. of urinary catheter–days	62,960	1,791 (1,322-3,275)

NOTE. Data are from 28 hospitals, except for number of surgical procedures ($n = 27$) and number of urinary catheter–days ($n = 27$). IQR, interquartile range.

$55,000 (IQR, $49,819-$62,500). The median annual cost of HAIs per hospital at these 17 hospitals was $519,702 (IQR, $361,857-$1,049,426) and $13.65 (IQR, $11.05-$24.66) per patient-day. Thus, the annual cost of HAIs at each hospital was a median of 4.6 (IQR, 3.4-8.0) times the amount budgeted for IC, a median of 4.3 (IQR, 3.3-8.7) times the amount budgeted for IC per patient-day, a median of 8.5 (IQR, 6.0-13.7) times the amount budgeted for payment of ICPs, and a median of 7.9 (IQR, 5.2-13.6) times the amount budgeted for payment of ICPs per patient-day.

The median amount budgeted for IC at smaller hospitals (<220 beds) was $100,000 (IQR, $80,000-$150,000), whereas the median amount budgeted for IC at larger hospitals ($\geqslant$220 beds) was $212,000 (IQR, $119,582-$420,000) ($P = .13$). As might be expected, the median amount budgeted for ICPs at smaller hospitals was less than the median amount budgeted for ICPs at larger hospitals ($53,999 vs $78,465; $P = .03$). Although the median amount budgeted for IC per patient-day was not significantly different between the 2 groups ($3.88 vs $2.51; $P = .13$), the median amount budgeted for ICPs per patient-day was actually higher at the smaller hospitals, compared with the larger hospitals ($2.45 vs $1.42; $P = .04$).

Cost Reduction Modeling

Cost reduction models based on absolute or relative reductions in rates of HAIs are listed in Table 4. All study models

resulted in substantial cost savings. For example, if all study hospitals were able to prevent as few as 4 additional HAIs (1 SSI, 1 VAP case, 1 HA-BSI, and 1 CA-UTI) in the next year, each hospital would save a median of $59,491 (IQR, $34,440-$59,508), and the study network would save a total of $1.4 million. If the study hospitals could prevent 25% of all HAIs, each hospital would save a median of $148,668 (IQR, $74,763-$296,861) annually, and the study network would save a total of $6.5 million.

DISCUSSION

The results of our study estimate the enormous financial burden that HAIs impose on community and tertiary care hospitals alike. Despite our use of conservative estimates and despite the fact that hospitals in our study had rates of HAIs at or below nationally published benchmark or median rates reported by the National Nosocomial Infections Surveillance system, the total annual cost attributable to HAIs was greater than $26 million for the group of 28 study hospitals; the annual median cost attributable to HAI was approximately $595,000 for an individual hospital.

Previously published reports have provided wide-ranging, confusing estimates for the cost of HAIs. In this study, we calculated weight-adjusted mean costs for specific HAIs in 2005 US dollars by using previously published matched cost

TABLE 3. Number and Estimated Costs of Healthcare-Associated Infections (HAIs) for Study Hospitals During 2004

	No. of infections		Rate of infections[a]		Cost of infections, 2005 US dollars	
HAI type	Overall	Per hospital, median (IQR)	Overall	Per hospital, median (IQR)	Overall	Per hospital, median (IQR)
HA-BSI	516	7.5 (4.5-26.5)	0.36	0.22 (0.14-0.41)	11,992,872	174,315 (104,589-615,913)
SSI	1,075	30 (13-61)	0.81	0.95 (0.51-1.35)	11,226,171	313,290 (135,759-637,023)
VAP	109	2 (0-4)	3.4	1.8 (0-5.3)	2,732,853	50,144 (0-100,288)
CA-UTI	257	4 (2-19)	4.1	2.7 (1.3-5.2)	194,780	3,032 (1,516-14,402)
Annual cost	...	...	...	...	26,146,450	594,683 (299,057-1,187,499)
Cost per patient-day	...	...	...	...	493	13.65 (11.82-24.33)

NOTE. CA-UTI, catheter-associated urinary tract infection; HA-BSI, healthcare-associated bloodstream infection; IQR, interquartile range; SSI, surgical site infection; VAP, ventilator-associated pneumonia.
[a] Data are number of HA-BSIs per 1,000 patient-days ($n = 28$ hospitals), number of SSIs per 100 procedures ($n = 27$ hospitals), number of VAP cases per 1,000 ventilator-days ($n = 28$ hospitals), and number of CA-UTIs per 1,000 catheter-days ($n = 27$ hospitals).

TABLE 4. Models for Reduction of Cost of Healthcare-Associated Infections (HAIs), According to Absolute and Relative Reductions in HAIs

Cost reduction model	Adjusted annual cost of HAI per hospital, median (IQR)	Cost reduction per hospital, median (IQR)	Adjusted cost of HAI per patient-day per hospital, median (IQR)	Cost reduction per patient-day per hospital, median (IQR)	Total cost reduction for study hospitals
Absolute reduction					
Prevent 4 HAIs[a]	535,372 (239,924-1,128,002)	59,541 (34,434-59,508)	12.36 (9.38-23.56)	1.05 (0.68-1.84)	1,405,584
Prevent 20 HAIs[b]	339,825 (104,430-953,944)	221,529 (170,314-256,830)	9.75 (4.28-18.51)	4.89 (3.08-6.76)	5,810,515
Relative reduction					
Prevent 5% of HAIs	564,952 (284,106-1,128,141)	29,730 (14,951-59,358)	12.97 (11.22-23.11)	0.68 (0.59-1.22)	1,307,037
Prevent 10% of HAIs	535,218 (269,154-1,068,765)	59,464 (29,904-118,734)	12.28 (10.63-21.89)	1.36 (1.18-2.43)	2,614,374
Prevent 25% of HAIs	446,015 (224,295-890,638)	148,668 (74,763-296,861)	10.24 (8.86-18.25)	3.41 (2.95-6.08)	6,536,387
Prevent 50% of HAIs	297,346 (149,532-593,777)	297,337 (149,526-593,722)	6.83 (5.91-12.16)	6.82 (5.91-12.16)	13,072,816

NOTE. Data are in 2005 US dollars.
[a] One surgical site infection (SSI), 1 healthcare-associated bloodstream infection (HA-BSI), 1 ventilator-associated pneumonia (VAP) case, and 1 catheter-associated urinary tract infection (CA-UTI).
[b] Five SSIs, 5 HA-BSIs, 5 VAP cases, and 5 CA-UTIs.

analyses and adjusting for inflation. We then applied these estimates to HAI surveillance information for a network of 28 community hospitals to determine the total financial burden of HAIs at these hospitals and for the network of hospitals as a whole.

HAIs are expensive. We estimated that the weight-adjusted average costs of VAP, HA-BSI, SSI, and CA-UTI were $25,072, $23,242, $10,443, and $758, respectively. In fact, these values likely underestimate the true costs of specific HAIs, because our estimates included only direct costs. In many studies on the cost of HAIs, including those studies used in this study, direct costs attributable to HAIs are estimated primarily on the basis of costs associated with increased length of stay. Thus, our cost estimates do not include opportunity costs for hospitals, indirect costs, costs after discharge (eg, for rehabilitation or nursing home stay), costs of rehospitalization, and costs to society (eg, loss of wages and productivity).[35] Additionally, patients with HAIs die more frequently than uninfected patients. Thus, even direct costs based on length of stay may be underestimated, because decreased length of stay as a result of in-hospital death leads to lower variable and discretionary costs.[36]

To our knowledge, only 1 previous study, by Stone et al.,[37] has attempted to determine the costs of specific HAIs on the basis of previously published literature. Their study, however, included studies that used highly variable methods to estimate the costs of specific HAIs. Stone et al.[37] used the following estimates to calculate the total cost of HAIs in their institution: $38,703 per HA-BSI, $17,677 per VAP case, and $15,646 per SSI. No cost estimates were given for CA-UTIs. The differences in cost estimates between our study and the study by Stone and colleagues likely arise from methodological differences. In contrast to the study by Stone et al.,[37] we included only studies that estimated costs due to HAIs by measuring incremental costs associated with diagnosing and treating HAIs. Additionally, we used a weight-adjustment method to give higher weight to larger studies, to reduce random error in cost differences.

The costs of HAIs are generally not reimbursed and are likely to become even less reimbursable in the future.[38] These costs adversely affect the operating margin for most hospitals but may be hidden to administrators, appearing as part of the costs of providing care but not specifically as a line item. DRG-based reimbursement is not altered when an individual patient develops an HAI, because no specific DRG codes are available for HAIs.[39] Indeed, only 22% of the diagnoses listed in the current DRG system provide additional payments when "complications" arise.[40] Thus, the current American prospective payment system, based on DRGs, does not reimburse hospitals adequately for HAIs.[41] Finally, as pay-for-performance incentives arise, the small amount of reimbursement that hospitals receive may be further reduced. Indeed, agencies such as the Centers for Medicare and Medicaid Services have proposed rules to eliminate any form of enhanced payment for the occurrence of a preventable HAI.[38]

Given the fact that hospitals do not receive reimbursement for more than 90% of the costs attributable to HAIs,[42] it would be sensible for hospitals to substantially invest in programs that reduce the occurrence of these infections. Yet, our study demonstrates that the annual budgets of most IC programs represent a small fraction of the cost of their annual losses due to HAIs. In a subgroup of 17 hospitals in our study, the total annual cost of HAIs dwarfed the amount budgeted for IC and prevention by a factor of 6. Additionally, the cost of HAIs per hospital was a median of 4.6 times the amount budgeted for IC and prevention per hospital and 8.5 times the amount budgeted for payment of ICPs per hospital. After adjusting for the size of the hospitals, the loss due to HAIs ($13.65 per patient-day) was 4.3 times the amount hospitals invested in their prevention ($3.52 per patient-day).

Several cost reduction models were presented in this study. In the Study of the Efficacy of Nosocomial Infection Control

published in 1985, IC programs reduced rates of HAIs by as much as 32%.[43] Indeed, in our own network, we were able to reduce the rate of nosocomial HA-BSIs by 23% and the rate of VAP cases by 40% during a 3-year period.[15] If all of the hospitals included in the current study were able to reduce the rates of all HAIs by an additional 25%, each hospital would save approximately $150,000, and the entire network would save more than $6 million. Even if a hospital were able to prevent only 1 additional VAP case, 1 additional SSI, 1 additional HA-BSI, and 1 additional CA-UTI per year, that hospital could prevent a loss of approximately $59,500, a sum that is greater than the median salary of ICPs presented in this study.

Recent reports suggest that much larger reductions in rates of HAIs are possible. For example, Muto et al.[44] recently reported a 68% reduction in intensive care unit central venous catheter–associated BSIs after implementation of a coordinated IC initiative. Babcock et al.[45] initiated an intensive educational program in the intensive care units of 4 hospitals and reduced the rate of VAP cases by 46%. If all IC programs in our study were ambitiously able to reduce their current numbers of HAIs by 50%, then each hospital would save more than $297,000 each year, and the entire network would save $13.1 million.

The limitations of our study are similar to the limitations of the studies we used for determining the cost estimates per HAI. For example, in matched analyses, the 2 groups being compared (a group with HAIs and a group without HAIs) may be matched by variables that increase the length of stay (eg, age and discharge diagnosis). One frequently cited caveat of these studies is that the matching method is often suboptimal and incomplete.[46] Thus, incompletely or inefficiently matched analyses that estimate attributable costs due to HAIs may overestimate direct costs by overestimating the length of stay attributable to HAIs. Additionally, our cost estimates may be falsely lowered. The total cost of HAIs for each hospital and the network includes only the costs of 4 specific HAIs. Other HAIs, such as *Clostridium difficile*–associated disease, superficial SSIs, and infections in employees and physicians due to bloodborne pathogen exposures, are not included in our study. Thus, despite the magnitude of the costs of HAIs measured at these hospitals, our study clearly underestimates the total cost attributable to all HAIs at the participating hospitals.

IC programs initially were created to satisfy regulatory requirements. More recently, IC has moved to the forefront of patient safety. Indeed, because rates of HAIs are an important metric for assessing patient safety, state legislatures in 14 states have written laws that require hospitals to measure and publicly report their rates of HAIs (as of June 30, 2006). Furthermore, JCAHO and the Institute for Healthcare Improvement have repeatedly emphasized that preventing HAIs improves patient safety.[6,7] The cumulative annual total costs attributable to HAIs were greater than $26 million in our cohort of 28 hospitals, based on conservative estimates for the costs of specific HAIs. Thus, in addition to patient safety,

the economics of HAIs must be included as an important metric for IC programs. Although nearly every hospital in the United States has a pressing need and plenty of incentive to reduce their local rates of HAIs, incremental benefits (eg, the money saved by preventing HAIs) remain far higher than incremental investments being made (eg, the costs of increasing resources for an IC program). Cost reduction projections of the efficacy of infection prevention programs are all based on the assumption that IC programs can actually prevent infections. However, little research has been performed on the usefulness of various prevention methods, and there has been even less research on the sustainability of effective prevention programs once they have been introduced. Our data suggest that such research is badly needed for financial reasons. Meanwhile the data we have presented can be used to bring additional attention to the incredible humanitarian and financial drain that HAIs impose. We believe that discussions of the potential return on investments made to prevent infection will become commonplace in the future. Furthermore, our data suggest that money invested in infection prevention activities will indeed yield substantial financial returns and simultaneously yield equally large dividends related to improving patient safety. In the end, such dividends may be of the most value to our patients and the healthcare system, allowing the healthcare system to become wise with both its pennies and pounds.

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REFERENCES

1. Boyce JM, Potter-Bynoe G, Dziobek L, Solomon SL. Nosocomial pneumonia in Medicare patients: hospital costs and reimbursement patterns under the prospective payment system. *Arch Intern Med* 1991; 151: 1109-1114.
2. Haley RW, Culver DH, White JW, Morgan WM, Emori TG. The nationwide nosocomial infection rate: a new need for vital statistics. *Am J Epidemiol* 1985; 121:159-167.
3. Jarvis WR. Selected aspects of the socioeconomic impact of nosocomial infections: morbidity, mortality, cost, and prevention. *Infect Control Hosp Epidemiol* 1996; 17:552-557.
4. Burke JP. Infection control: a problem for patient safety. *N Engl J Med* 2003; 348:651-656.
5. Jarvis WR. The state of the science of health care epidemiology, infection control, and patient safety, 2004. *Am J Infect Control* 2004; 32:496-503.
6. Institute for Healthcare Improvement. *100K Lives Campaign: Some Is*

Not a Number, Soon Is Not a Time. Cambridge, MA: Institute for Healthcare Improvement; 2006.

7. Joint Commission on Accreditation of Healthcare Organizations. *Joint Commission Standards.* Oakbrook Terrace, IL: Joint Commission on Accreditation of Healthcare Organizations; 2006.

8. Fraser VJ. Starting to learn about the costs of nosocomial infections in the new millennium: where do we go from here? *Infect Control Hosp Epidemiol* 2002; 23:174-176.

9. Lauria FN, Angeletti C. The impact of nosocomial infections on hospital care costs. *Infection* 2003; 31(suppl 2):35-43.

10. Baker AM, Meredith JW, Haponik EF. Pneumonia in intubated trauma patients: microbiology and outcomes. *Am J Respir Crit Care Med* 1996; 153:343-349.

11. Rello J, Ollendorf DA, Oster G, et al. Epidemiology and outcomes of ventilator-associated pneumonia in a large US database. *Chest* 2002; 122: 2115-2121.

12. Haley RW. Measuring the costs of nosocomial infections: methods for estimating economic burden on the hospital. *Am J Med* 1991; 91:32S-38S.

13. US Bureau of Labor Statistics. *Employment Cost Index.* Available at: http://www.bls.gov/web/ecconst.pdf. Accessed May 14, 2007.

14. Board of Governors of the Federal Reserve System. *US/Euro Foreign Exchange Rate.* Available at: http://research.stlouisfed.org/fred2/data/DEXUSEU.txt. Accessed May 14, 2007.

15. Kaye KS, Engemann JJ, Fulmer EM, Clark CC, Noga EM, Sexton DJ. Favorable impact of an infection control network on nosocomial infection rates in community hospitals. *Infect Control Hosp Epidemiol* 2006; 27:228-232.

16. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1988. *Am J Infect Control* 1988; 16:128-140.

17. Apisarnthanarak A, Jones M, Waterman BM, Carroll CM, Bernardi R, Fraser VJ. Risk factors for spinal surgical-site infections in a community hospital: a case-control study. *Infect Control Hosp Epidemiol* 2003; 24: 31-36.

18. Boyce JM, Potter-Bynoe G, Dziobek L. Hospital reimbursement patterns among patients with surgical wound infections following open heart surgery. *Infect Control Hosp Epidemiol* 1990; 11:89-93.

19. Coello R, Glenister H, Fereres J, et al. The cost of infection in surgical patients: a case-control study. *J Hosp Infect* 1993; 25:239-250.

20. Hollenbeak CS, Murphy DM, Koenig S, Woodward RS, Dunagan WC, Fraser VJ. The clinical and economic impact of deep chest surgical site infections following coronary artery bypass graft surgery. *Chest* 2000; 118:397-402.

21. Kirkland KB, Briggs JP, Trivette SL, Wilkinson WE, Sexton DJ. The impact of surgical-site infections in the 1990s: attributable mortality, excess length of hospitalization, and extra costs. *Infect Control Hosp Epidemiol* 1999; 20:725-730.

22. VandenBergh MF, Kluytmans JA, van Hout BA, et al. Cost-effectiveness of perioperative mupirocin nasal ointment in cardiothoracic surgery. *Infect Control Hosp Epidemiol* 1996; 17:786-792.

23. Vegas AA, Jodra VM, Garcia ML. Nosocomial infection in surgery wards: a controlled study of increased duration of hospital stays and direct cost of hospitalization. *Eur J Epidemiol* 1993; 9:504-510.

24. Whitehouse JD, Friedman ND, Kirkland KB, Richardson WJ, Sexton DJ. The impact of surgical-site infections following orthopedic surgery at a community hospital and a university hospital: adverse quality of life, excess length of stay, and extra cost. *Infect Control Hosp Epidemiol* 2002; 23:183-189.

25. Hugonnet S, Eggimann P, Borst F, Maricot P, Chevrolet JC, Pittet D. Impact of ventilator-associated pneumonia on resource utilization and patient outcome. *Infect Control Hosp Epidemiol* 2004; 25:1090-1096.

26. Kappstein I, Schulgen G, Beyer U, Geiger K, Schumacher M, Daschner FD. Prolongation of hospital stay and extra costs due to ventilator-associated pneumonia in an intensive care unit. *Eur J Clin Microbiol Infect Dis* 1992; 11:504-508.

27. Papazian L, Bregeon F, Thirion X, et al. Effect of ventilator-associated pneumonia on mortality and morbidity. *Am J Respir Crit Care Med* 1996; 154:91-97.

28. Warren DK, Shukla SJ, Olsen MA, et al. Outcome and attributable cost of ventilator-associated pneumonia among intensive care unit patients in a suburban medical center. *Crit Care Med* 2003; 31:1312-1317.

29. Chen YY, Chou YC, Chou P. Impact of nosocomial infection on cost of illness and length of stay in intensive care units. *Infect Control Hosp Epidemiol* 2005; 26:281-287.

30. Digiovine B, Chenoweth C, Watts C, Higgins M. The attributable mortality and costs of primary nosocomial bloodstream infections in the intensive care unit. *Am J Respir Crit Care Med* 1999; 160:976-981.

31. Orsi GB, Di Stefano L, Noah N. Hospital-acquired, laboratory-confirmed bloodstream infection: increased hospital stay and direct costs. *Infect Control Hosp Epidemiol* 2002; 23:190-197.

32. Pirson M, Dramaix M, Struelens M, Riley TV, Leclercq P. Costs associated with hospital-acquired bacteraemia in a Belgian hospital. *J Hosp Infect* 2005; 59:33-40.

33. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients: excess length of stay, extra costs, and attributable mortality. *JAMA* 1994; 271:1598-1601.

34. Moris de la Tassa J, Fernandez Munoz P, Antuna Egocheaga A, Gutierrez del Rio MC, Carton Sanchez JA. Estimating the costs associated with nosocomial urinary tract infection: a case-control study. *Revista Clinica Espanola* 2003; 203:119-124.

35. Wenzel RP. The Lowbury Lecture: the economics of nosocomial infections. *J Hosp Infect* 1995; 31:79-87.

36. Graves N. Economics and preventing hospital-acquired infection. *Emerg Infect Dis* 2004; 10:561-566.

37. Stone PW, Larson E, Kawar LN. A systematic audit of economic evidence linking nosocomial infections and infection control interventions: 1990-2000. *Am J Infect Control* 2002; 30:145-152.

38. Medicare program; prospective payment system for long-term care hospitals RY 2007: annual payment rate updates, policy changes, and clarification: final rule. *Federal Register* 2006; 71:27797-27939.

39. *Revised ICD-9-CM DRG Definitions Manual, Version 18.0.* 18th ed. Murray, UT: 3M Health Information Systems; 2002.

40. Farber BF. Reimbursement for nosocomial infections under the prospective payment plan: the future or decline of infection control? *Infect Control* 1984; 5:425-426.

41. Boyce JM, Dziobek L, Potter-Bynoe G. Reimbursement for nosocomial infections. *Ann Intern Med* 1988; 108:776.

42. Haley RW, White JW, Culver DH, Hughes JM. The financial incentive for hospitals to prevent nosocomial infections under the prospective payment system: an empirical determination from a nationally representative sample. *JAMA* 1987; 257:1611-1614.

43. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. *Am J Epidemiol* 1985; 121:182-205.

44. Reduction in central line-associated bloodstream infections among patients in intensive care units: Pennsylvania, April 2001–March 2005. *MMWR Morb Mortal Wkly Rep* 2005; 54:1013-1016.

45. Babcock HM, Zack JE, Garrison T, et al. An educational intervention to reduce ventilator-associated pneumonia in an integrated health system: a comparison of effects. *Chest* 2004; 125:2224-2231.

46. Wakefield DS, Pfaller MA, Hammons GT, Massanari RM. Use of the appropriateness evaluation protocol for estimating the incremental costs associated with nosocomial infections. *Med Care* 1987; 25:481-488.