THE DIRECT MEDICAL COSTS OF
Healthcare-Associated Infections in U.S. Hospitals and the Benefits of Prevention

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SUMMARY

This report uses results from the published medical and economic literature to provide a range of estimates for the annual direct hospital cost of treating healthcare-associated infections (HAIs) in the United States. Applying two different Consumer Price Index (CPI) adjustments to account for the rate of inflation in hospital resource prices, the overall annual direct medical costs of HAI to U.S. hospitals ranges from $28.4 to $33.8 billion (after adjusting to 2007 dollars using the CPI for all urban consumers) and $35.7 billion to $45 billion (after adjusting to 2007 dollars using the CPI for inpatient hospital services). After adjusting for the range of effectiveness of possible infection control interventions, the benefits of prevention range from a low of $5.7 to $6.8 billion (20 percent of infections preventable, CPI for all urban consumers) to a high of $25.0 to $31.5 billion (70 percent of infections preventable, CPI for inpatient hospital services).

I. INTRODUCTION

Healthcare-associated infections (HAIs) in hospitals impose significant economic consequences on the nation's healthcare system. The most comprehensive national estimate of the annual direct medical costs due to HAIs (published in 1992) was based on the results from the Study on the Efficacy of Nosocomial Infection Control (SENIC) that was conducted in the mid-1970s. [1] With an incidence of approximately 4.5 HAIs for every 100 hospital admissions, the annual direct costs on the healthcare system were estimated to be $4.5 billion in 1992 dollars.[1] Adjusting for the rate of inflation using the CPI for all urban consumers, this estimate is approximately $6.65 billion in 2007 dollars. However, more recent published evidence indicates that the underlying epidemiology of HAIs in hospitals has changed substantially since the SENIC study, along with the costs of treating HAI. [2, 3] The purpose of this report is to update the annual national direct medical costs of HAIs based on published studies selected for this analysis. As there has not been another national study since the SENIC project, national estimates must be inferred from studies based on more limited study settings. Therefore, only ranges of costs will be provided to reflect the uncertainty that results from using published cost estimates from studies with more limited scope.

While this report itself is not a meta-analysis or a systematic review, there were three criteria used to identify the most appropriate cost estimates for use in this analysis. First, the study investigators must have conducted their economic analysis from the cost perspective of the hospital. Second, the estimate must be from either a multi-center study, a systematic review, or a single-center study that estimated the cost of an HAI for most, if not all, of a hospital population (as opposed to a specific setting such as an intensive care unit). Finally, the investigators must have used either actual costs (micro-costing methods) or hospital charges that were adjusted using a cost-to-charge ratio to represent the actual opportunity cost of the hospital resources used.

The next section of this report begins with the justification for the three criteria used to select the published evidence to develop cost estimates. In the third section, the annual national cost estimates for five different infection sites will be developed, including surgical site infections (SSIs), central line associated bloodstream infections (CLABSIs), ventilator-associated pneumonias (VAPs), catheter-associated urinary-tract infections (CAUTIs), and Clostridium difficile-associated disease (CDI). Cost estimates for each of the various infection sites are inferred from published studies and combined with annual HAI incidence estimates from the National Nosocomial Infection Surveillance System (NNIS). The fourth section develops an estimate of the annual national direct medical costs of all HAIs to U.S. hospitals. Given the different epidemiologic methods (retrospective cohort, prospective observational) and costing methods (actual expenditures, charges, cost-to-charge ratios) used in studies of HAIs, it should be acknowledged that the cost estimates from the separate infection site studies do not lend themselves to simple addition for the purposes of creating an aggregate cost estimate for all HAIs. To estimate the overall national direct medical cost of all HAIs, this analysis used results from two studies employing different study methodologies: a systematic review of economic studies and an economic model of hospital-wide patient costs from a single hospital. A sensitivity analysis is also conducted that takes into account the uncertainty associated with the effectiveness of infection control programs and the proportion of HAIs that are preventable in order to assess the potential opportunity costs that HAIs impose on hospitals.

II. Justification of Study Criteria

The hospital perspective on the Cost of HAI

Three broad components of cost comprise the socio-economic costs of HAI: direct medical costs, the indirect costs related to productivity and non-medical costs, and intangible costs related to diminished quality of life (Table 1). The vast majority of economic and cost analyses of HAI focus primarily on direct medical costs as these costs directly impact hospital finances. Given the current Diagnosis Related Group classification system does not have specific codes for HAIs, hospitals may not be able to recover the extra patient costs to treat HAIs from third party payers.[1] Most researchers perform their analysis from the hospital perspective only to provide evidence that hospitals can see economic benefits through investment in infection control programs. However, there are other analytical perspectives that incorporate broader interpretations of the costs of HAIs, particularly in terms of the economic impacts resulting from diminished worker productivity (resulting from additional morbidity due to an HAI) or the loss of life. While such impacts affect patients, third party payers and society as a whole, there is little empirical evidence on the costs associated with these long term outcomes. Additionally, these impacts probably do not affect hospital administration and decision making. For the purposes of this report, only studies that provide evidence on the direct hospital costs associated with treating HAIs are considered.

Study Designs

The most common analytical approach for measuring the cost of HAIs by infection site usually employs some type of observational epidemiologic study in which a group of patients not infected with a specific microorganism is compared to a group of infected (or exposed) patients.[5,6] However, study populations and methods vary and include differing economic evaluation methods (cost analysis, cost-effectiveness analysis, or cost-benefit analysis), observational study designs (prospective versus retrospective, concurrent versus comparative design, matched versus unmatched analysis, selection and number of confounders used), patient populations and settings (e.g. ICU, specific disease), and cost information used (charges, adjusted charges, or micro-cost data).[6] A recent systematic review of the economic analyses of HAIs conducted by Stone and colleagues noted that, given the differences in study methods, the published literature on the cost of HAI shows considerable variation in the cost estimates for the various sites of infection.[3] As the purpose of this report is to provide representative cost estimates for the entire population of infected patients with any HAI, the analysis reported here considered only cost estimates from systematic reviews or studies that were based on larger, hospital-wide study populations that captured more of the potential variation in hospital costs in patients with an HAI.

Cost Information

An important consideration for any economic evaluation of resource use in hospitals is distinguishing between actual micro-costs (the expenditures the hospital makes for goods and services) and charges (what the hospital charges the patient). [7,8] Micro-costing provides more precise estimates of the economic value of the resources used in hospital care. However, the prospective payment system currently used by the CMS and other third party payers to set reimbursement rates for hospitals for their services can lead to distortions in patient costs referred to as cost shifting. Here, hospitals will raise charges above the amount that

[1] Under the Prospective Payment System used by the Centers for Medicare and Medicaid Services (CMS), the level of reimbursement to hospitals for patient care is set according the Diagnosis Related Group (DRG) classification system. This system classifies hospital patients into groups of patients expected to consumeuse the same level of hospital resources based on a number of different patient characteristics including gender, age, diagnosis, types of procedures, and any co-morbidities present on admission.[4] This same classification system is also used by other third party payers to set their reimbursement rates.

would accurately reflect actual patient costs to payers with more generous reimbursement schedules which, in effect, subsidizes less generous payers as well as patients who cannot pay for their own care. Thus, the use of hospital charges to reflect the costs of patient care can overestimate the actual costs of resources consumed. [9,10] Similarly, cost shifting can occur within the hospital when some services are reimbursed at a higher rate than others. Because micro-costing provides cost information that more accurately reflects the opportunity costs of resources used to treat infected patients, only cost estimates based on micro-cost data, or alternatively, cost estimates based on charges that have been adjusted to more accurately reflect actual hospital expenditures on patient care are used for this report. Such adjustments include using published cost-to-charge ratios provided by CMS, or a hospital's own internal cost-to-charge ratios based on their own reimbursement agreements with third party payers.

III. Estimates of the annual direct medical costs for five HAI sites

Estimates of the direct medical costs associated with five major sites of HAIs will be calculated by taking estimates of the number of infections and then multiplying these estimates with both a low and a high average patient cost estimate from the published literature. The patient cost estimates are adjusted for the rate of infection using two different inflation indexes: the CPI for all urban consumers (CPI-U) and the CPI for inpatient hospital services with all cost estimates adjusted to 2007 dollars. As the various studies used in this report were conducted at different points in time, the cost estimates must be adjusted to 2007 dollars in order to make them comparable. As both indexes measure price changes for broadly defined expenditure groups, there is no research to date on which measure would be most appropriate to use to accurately adjust for inflation in the prices of the hospital resources used to treat HAIs. Given the potential to mismeasure the rate of inflation on these resources prices, all cost estimates will be adjusted using both indexes. A description of the construction and composition of each consumer price index and the potential limitations of each index to adjust cost estimates of HAI follows below.

Consumer Price Indexes

The CPI-U is constructed by the U.S. Bureau of Labor Statistics (BLS) and is a measure of the average change over time in the prices paid by all urban consumers (defined as all urban households in Metropolitan Statistical Areas and in urban places of 2,500 inhabitants or more) for a market basket of consumer goods and services purchased for day-to-day living. The all urban consumer group includes almost all residents of urban or metropolitan areas, including professionals, the self-employed, the poor, the unemployed, and retired people, as well as urban wage earners and clerical workers and represents about 87 percent of the total U.S. population.[11] The goods and services that are included in the CPI market basket have been determined from an annual BLS survey on consumer expenditures which provides detailed information on consumer spending habits. Combining the consumer expenditure data with other survey data on prices from retails outlets, the CPI-U is updated on a monthly basis. The various goods and services that consumers purchase are classified into over 200 categories that fall into eight major classification groups including food and beverages, housing, apparel, transportation, medical care, recreation, educational and communication, and a final group representing other goods and services. As an estimate of the percent change in prices between any two price periods, the CPI-U is the most widely used measure of inflation and is used by federal and state governments to adjust government income payments or to make cost-of-living adjustments to wages.

The inpatient hospital services index is a subcategory of the expenditure items found under the medical care major expenditure group (Table 2). The medical care expenditure group is divided into subcategories that include two intermediate groups: medical care commodities and medical care services. The medical care services intermediate group is composed of two expenditure classes that include professional services and hospital services. The CPI for hospital inpatient services is a one of two item strata (or subsets) that comprises the hospital services expenditure group (the other item being outpatient hospital services). This inpatient hospital services index is derived from a survey of price changes for goods and services that hospitals (also in urban areas) consume while treating a patient during a hospital visit. A hospital visit consists of a bundle of goods and services that are used to achieve a desired outcome, regardless of the length of the hospital stay, and is based on the contents of a "live" hospital bill that is submitted to a payer that reflects actual hospital service delivery patterns.[12] As the CPI is used to measure out-of-pocket expenditures by the consumer, only payments made by either a private insurer and/or the patient are considered (payments by employer provided insurers, along with payments by Medicare and Medicaid are excluded). [12] The goods and services in this index include a mixture of itemized services (such as lab tests, emergency room visits), diagnosis related group (DRG) based services, daily room charges etc., but treats them as a bundle of complementary services provided by hospitals during a hospital visit (as opposed to pricing each item consumed separately) whose value is determined by surveying payer reimbursements or other set fee schedules. Table 2 presents the annual percentage change in prices for the years 2001-2007 for the CPI-U, the medical care expenditure group, and other subcategories related to hospital services including the inpatient hospital services index. The increase in prices (or the level of inflation) as measured by CPI-U has been lower compared to the price increases measured by the various indexes for the medical care and hospital services, reflecting the higher level of inflation as measured in these more narrowly defined indexes. For 2007, the CPI-U increased 2.8 percent from 2006 while the CPI for hospital related services and CPI for inpatient hospital services increased 6.6 percent and 6.3 percent respectively.

In this report, both the CPI-U index and the CPI for inpatient hospital services are used to adjust the various cost estimates to 2007 dollars. Given that the CPI-U is a broad measure of price changes for a market basket of goods comprised of a number of different expenditure groups, the use of CPI-U index might understate the rate of inflation on the prices of the hospital resources used to treat HAIs given that inflation in medical services has been higher than the CPI-U. While the CPI for hospital inpatient services is a more narrowly defined expenditure subcategory for hospital resources, it is possible this index might over inflate price increases that results from the adoption of new medical technology (i.e. new diagnostic tools, drugs, procedures, etc.). Without adjusting for the improvement in patient outcomes due to new technology, the CPI for hospital inpatient services can overstate price changes.[13] As both indexes may misrepresent the actual impact of inflation on the resources used to treat HAI, both are used to adjust the range of HAI cost estimates from the published studies used in this report.

Estimates for the number of HAIs

The estimates for the number of infections, except for CDI, are based on estimates from Klevens et al. [14] As the estimates from the Klevens et al. incorporate both device and non-device related infections, these numbers are adjusted to provide estimates of the number of device-related infections by each site (Table 3) to be consistent with the cost information from the literature which has focused on device-related infections. The proportions used to make the adjustments to the total number of BSIs (37 percent device-related) and pneumonia (21 percent device-related) are based on a study by Weber et al., while the proportion for urinary tract infections (80 percent device-related) is based on a study by Saint et al.[15, 16] The estimate for the number of CDIs cases comes from a study by McDonald et al. (2003). [17]

Two recent systematic reviews of the published literature on the costs associated with various HAIs in hospitals are available. Updating a previous review from 2002, Stone et al. derived the following attributable cost estimates: $25,546 for SSI, $36,441 for BSI, $9,969 for VAP and $1,006 for CAUTI.[3] These authors did note that there was considerable variation in the cost methodology used by the studies incorporated in their review which included results from vaccination studies as well as studies on community-acquired infections. Anderson et al. [18] also developed estimates of the cost of HAIs from published studies but used a more stringent inclusion criterion by including only studies that estimated the attributable costs of getting an HAI. Anderson et al. weighted the various cost results by giving higher weight to estimates from larger studies. The resulting attributable costs of various HAIs included: $10,443 for SSI, $23,242 for BSI, $25,072 for VAP, and $758 for CAUTI.

The results from both systematic studies have limitations and must be used with caution. As an example, the nine studies used by Stone et al. to estimate the mean cost attributable to BSI included five studies from outside the U.S., while three of the four U.S. studies used charges (as opposed to actual costs). Likewise, the five studies used by Anderson et al. to estimate the cost of BSI included three non-U.S. studies, while the two U.S. studies were based on ICU populations only. Given the lack of consistency between locations, populations and cost information from the studies in these systematic reviews, this report also used cost estimates from other single hospital studies that incorporated both hospital-wide study settings and micro-cost data in their analysis. The studies selected for their direct medical cost estimates for each infection site are described below.

SSI

Starting with SSIs, the studies used for the average attributable cost of SSIs include Anderson et al. [18] for a low estimate ($10,443 per infection in 2005 dollars) and Stone et al. [3] for a high estimate ($25,546 per infection in 2002 dollars).

CLABSI

The cost estimates for CLABSIs were taken from a cost-effectiveness analysis to measure the impact of using maximal sterile barriers to prevent CLABSIs conducted by Hu et al.[19] In evaluating the literature, the study authors developed a range of estimates for the attributable cost of CLABSI ($5,734 to $22,939 in 2003 dollars) that would be representative of all hospitalized patients.

VAP

The studies used for the estimates on VAP include a low estimate from Warren et al.[20] and a high estimate from Anderson et al.[18] The Warren study examined the cost of VAP in intensive care patients, but the setting involved a nonteaching, suburban medical center rather than an urban or university tertiary care and teaching center where a majority of cost studies are usually performed. From this study, the average attributable patient cost of VAP is $11,897 (in 1999 dollars). The estimate of the cost of VAP from Anderson et al is $25,072 (in 2005 dollars).

CAUTI

For costs associated with CAUTI, the Anderson et al. [18] study provides an estimate of $758 per infection. The second estimate of $589 (in 1998 dollars) comes from Tambyah et al. [21]. While the Tambyah et al. study is a single-center study, it was a hospital-wide prospective study. Because of the differing CPI adjustments, the higher estimate using the CPI for all urban consumers comes from the Anderson study, while the higher estimate using the CPI for inpatient hospital services comes from the Tambyah study.

CDI

Few studies have estimated the cost of hospital-associated CDI. The estimate used here comes from a study by Dubberke et al. [22]. This is a single-center, retrospective cohort study; however, two different methods were used to estimate costs and the analytic time horizon was 180 days (from the index hospital admission) to capture any potential readmissions resulting from CDI. The lower bound estimate of $5,042 was determined using linear regression analysis while the higher estimate of $7,179 was determined using propensity-score matched-pairs analysis. These estimates are conservative as they did not include any patients that had any operating room costs associated with their hospital stay. Both estimates were in 2003 dollars.

Range of cost estimates by infection site

The estimates developed for each infection site and their CPI-adjusted values are displayed in Tables 4 and 5. Starting with a low and a high cost estimate from selected studies in Table 4, these estimates are than adjusted to 2007 dollars using the CPI-U and the CPI for inpatient hospital services. Using the results from Table 4, Table 5 presents the estimated ranges of the total annual costs associated with specific sites of HAI infection in U.S. hospitals adjusted by the two CPI indexes. The infection site with the largest range of annual costs is SSI ($3.2 billion to $8.6 billion using the CPI-U and $3.5 billion to $10 billion using the CPI for inpatient hospital services) while the site with the smallest annual cost is CAUTI ($340 million to $370 million using the CPI-U and $390 million to $450 million using the CPI for inpatient hospital services). The costs associated with the remaining infection sites are also significant with the direct medical cost of CLABSI , VAP, and CDI ranging from $590 million (adjusted by CPI-U) to $2.68 billion (adjusted by CPI for inpatient hospital services), $780 million (adjusted by CPI-U) to $1.5 billion (adjusted by CPI for inpatient hospital services), and $1.01 billion to $1.62 (adjusted by CPI for inpatient hospital services), respectively.

IV. Estimates of the cost of all HAIs in general

Studies Used

While published studies on the cost of HAIs tend to focus on a single device-related infection site (thus requiring adjustments to the counts of each separate infection site as done in the previous section), there are two published cost estimates available that are appropriate for assessing the overall direct patient costs of all HAIs (both device-related and non-device-related infections) using the estimated annual total number of HAIs (1,737,125 from the Klevens study) for 2002. An earlier systematic review of the economic costs of HAI conducted by Stone et al. included an estimate of the average attributable patient costs of HAIs in general.[23] The inclusion criteria for this review included papers published (in English) between 1990 and 2000 that contained abstracts and original cost estimates. The collected cost data were converted into U.S. dollars (for studies conducted outside the U.S.) and all dollar values were adjusted to 2001 dollars. The resulting mean estimate of $13,973 (with a standard deviation of $17,998) was based on nine selected studies. The large standard deviation associated with the mean estimate is probably due to the variety of study locations (inside and outside the U.S.) and costing methods (actual costs and hospital charges) employed by the study investigators.

The Roberts et al. study was a single-center study that measured the attributable costs associated with HAI in a hospital-wide random sample of adult medical patients.[24] The study used unit costs that were derived from the hospital expenditure report. The study excluded certain patient subpopulations who acquired an HAI in hospital service departments (pediatric, surgical, trauma, obstetrical wards) where the cost structures are significantly different from other hospital service wards. Exclusion of these locations from the analysis introduces a downward bias in the estimate of overall HAI cost. A multivariate regression model was analyzed using total patient costs as a dependent variable with APACHE III score, ICU admission, surgery, and the presences of an HAI as independent variables. The mean attributable cost of HAI of $15,275 (with a standard deviation of $5,491), in 1998 dollars, from the model represents a conservative cost estimate of HAI.

The National Annual Direct Hospital Costs of HAI Tables 6 shows the CPI adjustments made for the range of estimates on the average attributable per patient costs for all HAIs from the selected studies. Table 7 presents the overall annual direct medical costs to U.S. hospitals of all HAIs among hospital patients. The direct cost ranges from $28.4 to $33.8 billion adjusting for the rate of inflation using CPI-U. Using the CPI for inpatient hospital services, the overall direct cost ranges from $35.7 billion to $45 billion.

While the cost estimates illustrate the magnitude of the potential savings of preventing all infections, these savings must be weighted against the effectiveness of the interventions to prevent them and the cost of the resources needed to invest in the interventions. In assessing the extent that HAIs are preventable, Harbarth et al. [25] concluded that the literature provides no clear answers. In conducting a systematic review of the published evidence on the preventable proportion of HAIs resulting from multi-modal interventions, the authors found considerable variability in impacts, ranging from a 10 percent reduction to 70 percent reduction in HAIs. Interventions focusing on reducing CLABSI had the greatest impact with observed reductions ranging from 38 percent to 71 percent. Pronovost et al. [26] observed a 66 percent decrease in CLABSIs from their multi-modal intervention for all ICU units in hospitals located in Michigan. A similar decrease in CLABSIs has also been observed in ICU units in southwestern Pennsylvania after the implementation of a multi-faceted intervention that included targeted, evidence based insertion practices and an education program on prevention strategies.[27] However, the Harbarth study concluded that approximately 20 percent of all HAIs are probably preventable based on current medical practice and technology.

To reflect the uncertainty associated with the effectiveness of infection control prevention efforts, Table 8 presents the range of cost estimates after adjusting for prevention effectiveness levels of 20 percent, 50 percent and 70 percent. After these adjustments, the benefits of prevention range from a low of $5.7 to $6.8 billion (20 percent of infections preventable, 2007 CPI-U) to a high of $25.0 to $31.5 billion (70 percent of infections preventable, 2007 CPI for inpatient hospital services).

Discussion

While there is considerable variability in the costs of HAI, the low cost estimates of $5.7 to $6.8 billion annually are still substantial when compared to the cost of inpatient stays for other medical conditions. According to the Agency for Healthcare Research and Quality, the three principle diagnoses with the highest annual aggregate inpatient hospital costs (in 2006 dollars) include coronary artery disease ($17.5 billion), heart attach ($11.8 billion) and congestive heart failure ($11.2).[27] Even if the effectiveness of HAI prevention is low, the direct medical cost of preventable HAIs are comparable to the costs of stroke ($6.7 billion), diabetes mellitus with complications ($4.5 billion), and chronic obstructive lung disease ($4.2 billion).[28]

There are several important study limitations to consider when interpreting and using the cost estimates reported here. First, the national cost estimates have been inferred from studies with more limited study settings (regional or single hospital). To reflect the uncertainty associated with the representativeness of these studies, the national estimates have been presented as ranges. Second, it should be emphasized that this analysis is based on the estimated number of infections that occurred in 2002. As noted in the previous section above, the incidence of some types of infections (particularly CLABSIs) have been shown to be on the decline, whereas it is possible that the incidence of other HAIs may have changed (either increased or decreased) as well. Therefore, the estimated benefits of preventing HAIs for 2007, using 2002 infection data, is only an approximation of the actual benefits for 2007. Also, the published 2002 national estimates of the number of HAIs, in total and by site of infection, did not include information on the statistical uncertainty (or standard errors) associated with using NNIS hospitals as a sample for all hospitals in the United States. If this information were used in this analysis, the cost ranges presented here would be wider for they would now also reflect the variability in the estimated number of HAIs. Third, the proportions used to estimate the number of device-related infections from the total number of HAIs is based on a single study of HAI surveillance for a single hospital and may not be representative for all hospitals nationwide. Finally, this study did not attempt to provide any assessment of the cost associated with any interventions (outside the normal working conditions for established infection control programs) that would be used to curb HAIs. Such intervention costs will certainly reduce the magnitude of the direct medical cost savings (or benefits) and must be considered in any cost-effectiveness or cost-benefit analysis of infection control policies and programs.

References

1. Martone WJ, Jarvis WR, Culver DH, Haley RW. Incidence and nature of endemic and epidemic nosocomial infections. In: Bennett JV, Brachman PS, eds. Hospital infections. Boston: Little, Brown, and Company, 1992;577-96.

2. Haas JP. Measurement of infection control department performance: state of the science. *Am J Infect Control* 2006;34:545-9.

3. Stone PW, Braccia D, Larson E. Systematic review of economic analyses of health care-associated infections. *Am J Infect Control* 2005;33:501-509.

4. Diagnosis Related Groups (DRGs) and the Medicare Program: Implications for Medical Technology – a Technical Memorandum (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-TM-H-17, July 1983).

5. Haley RW. Measuring the cost of nosocomial infections: methods for estimating economic burden on the hospital. Am J Med 1991; 91 (suppl 3B):32S-38S.

6. Scott RD II, Roberts RR. The attributable cost of resistant infections in hospitals settings: economic theory and applications. In: Owens RC, Lautenbach E, eds. Antimicrobial Resistance: Problem Pathogens and Clinical Countermeasures. New York : Informa Healthcare, 2008:1-24.

7. Finkler SA. The distinction between cost and charges. *Ann Intern Med* 1982;96: 102-109.

8. Haddix AC, Schaffer PA. Cost-effectiveness analysis. In: Haddix AC, Teutsch SM, Shaffer PA, Dunet DO, eds. Prevention Effectiveness: A Guide to Decision Analysis and Economic Evaluation. New York: Oxford University Press, 1996: 103-129.

9. Dranove D. Pricing by non-profit institutions: the case of hospital cost shifting. *J Health Econ* 1988;7:47-57.

10. Dor A, Farley DE. Payment source and the cost of hospital care: evidence from a multiproduct cost function with multiple payers. *J Health Econ* 1996;15:1-21.

11. Bureau of Labor Statistics. BLS Handbook of Methods, Chapter 17, The Consumer Price Index. [cited 2008, Nov. 13]. http://www.bls.gov/opub/hom/pdf/homch17.pdf

12. Cardenas EM. Revision of the CPI hospital services component. *Monthly Labor Review* 1996;12:40-48.

13. Swick R, Bathgate D, Horrigan M. Services Producer Price Indices: Past, Present, and Future. Draft Paper. U.S. Bureau of Labor Statistics. May 26, 2006. [cited 2008, Oct. 10]. http://www.bls.gov/bls/fesacp1060906.pdf

14. Klevens RM, Edwards JR, Richards CL, Horan T, Gaynes R, Pollock D, Cardo D. Estimating healthcare-associated infections in U.S. hospitals, 2002. *Public Health Reviews* 2007;122:160-166.

15. Weber DJ, Sickert-Bennett EE, Brown V, Rutala WA. Comparison of hospitalwide surveillance and targeted intensive care unit surveillance of healthcare-associated infections. Infect Control Hosp Epidemiol 2007;28: 1361-1366.

16. Saint S, Crawford CE. Biofilms and catheter-associated urinary tract infections. *Infect Dis Clin N Am* 2003;17:411-432.

17. McDonald LC, Owings M, Jernigan DB. *Clostridium difficile* infection in patients discharged from US short-stay hospitals, 1996-2003. *Emerg Infect Dis* 2006;12:409-15.

References (*continued*)

18. Anderson DJ, Kirkland KB, Kaye KS, Thacker PA, Kanafani ZA, Sexton DJ. Underresourced hospital infection control and prevention programs: penny wise, pound foolish? *Infect Control Hosp Epidemio*l 2007;28:767-773.

19. Hu KK, Veenstra DL, Lipsky BA, Saint S. Use of maximal sterile barriers during central venous catheter insertion: clinical and economic outcomes. *Clin Infect Dis* 2004;39:1441-1445

20. Warren DK, Shukla DJ, Olsen MA, Kollef MH, Hollenbeak CS, Cox MJ, Cohen MM, Fraser VJ. Outcome and attributable cost of ventilator-associated pneumonia among intensive care unit patients in a suburban medical center. Crit Med Care 2003; 31:1312-1317.

21. Tambyah PA, Knasinski V, Maki DG. The direct cost of nosocomial catheter-associated urinary tract infection in the era of managed care. *Infect Control Hosp Epidemiol* 2002;23:27-31.

22. Dubberke ER, Reske KA, Olsen MA, McDonald LC, Fraser VJ. Short- and long-term attributable costs of *Clostridium Difficile*-associated disease in nonsurgical patients. *Clin Infect Dis* 2008;46:497-504.

23. 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.

24. Roberts RR, Scott RD II, Cordell R, Solomon SL, Steele L, Kampe LM, Trick WE, Weinstein RA. The use of economic modeling to determine the hospital costs associated with nosocomial infections. Clinical Infectious Diseases 2003;36:1424-32.

25. Harbarth S, Sax H, Gastmeier P. The preventable proportion of nosocomial infections: an overview of published reports. *J Hosp Infect* 2003;54:258-266.

26. Pronovost P, Needham D, Berenholtz S, Sinopoli D, Chu H, Cosgrove S, Sexton B, Hyzy R, Welsh R, Roth G, Bander J, Kepros J, Goeschel C. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 2006:355;2725-32.

27. Muto C, Harrison E, Edward JR, Horan T, Andus M, Jernigan JA, Kutty PK. Reduction in central line-associated bloodstream infections among intensive care units- Pennsylvania, April 2001- March 2005. *MMWR Wkly* 2005;54(40):1013-1016.

28. Levit K (Thomson Reuters), Stranges E (Thomson Reuters), Ryan K (Thomson Reuters), Elixhauser A (AHRQ). *HCUP Facts and Figures, 2006: Statistics on Hospital-based Care in the United States.* Rockville, MD: Agency for Healthcare Research and Quality, 2008. http://www.hcup-us.ahrq.gov/reports.jsp

Table 1: The Social Costs of Hospital-Associated Infections

Categories of Cost*		
Direct Hospital Costs	Fixed Costs	Buildings Utilities Equipment/Technology Labor (laundry, environmental control, administration)
	Variable Cost:	Medications Food Consultations Treatments Procedures Devices Testing (laboratory and radiographic) Supplies
Indirect Costs	Lost/Wages Diminished worker productivity on the job Short term and long term morbidity Mortality Income lost by family members Forgone leisure time Time spent by family/friends for hospital visits, travel costs, home care	
Intangible Cost	Psychological Costs (i.e., anxiety, grief, disability, job loss) Pain and suffering Change in social functioning/daily activities	

*Adapted from Haddix AC and Shaffer PA. Cost-effectiveness analysis. In Prevention Effectiveness: A Guide to Decision Analysis and Economic Evaluation. Oxford University Press, 1996.

Table 2: Consumer Price Index for Urban Consumers (CPI-U): U.S. city average by select expenditure category and commodity and service group*

Expenditure Category	Percentage change 12 months ended in December						
	2001	2002	2003	2004	2005	2006	2007
All items (CPI-U)	1.6	2.4	1.9	3.3	3.4	2.5	4.1
Medical Care	4.7	5.0	3.7	4.2	4.3	3.6	5.2
Medical Care Services	4.8	5.1	4.5	5.0	4.8	4.1	5.3
Hospital and Related Services	6.6	8.7	7.3	5.9	5.3	6.4	6.6
Hospital Services	6.6	9.0	7.4	6.0	5.3	6.5	6.7
Inpatient Hospital Services	6.3	8.4	6.8	5.7	5.7	7.0	6.3
Outpatient Hospital Services	6.6	10.2	9.1	5.4	4.7	5.9	7.4
Nursing Home and Adult Daycare	4.1	5.0	5.7	3.8	3.3	4.1	5.7

*Source: Bureau of Labor Statistics. Consumer Price Index Detailed Reports. [cited 2008, Nov. 13]. Available at www.bls.gov/cpi/cpi_dr.htm

Table 3: Estimated Number of HAIs by site of infection[14]

Major site of Infection	Estimated Number of Infections
Healthcare-Associated Infection (all HAI)	1,737,125
Surgical Site Infection (SSI)	290,485
Central Line Associated Bloodstream Infections (CLABSI)*	92,011
Ventilator-associated Pneumonia (VAP)**	52,543
Catheter associated Urinary tract Infection (CAUTI)***	449,334
Clostridium difficile-associated disease (CDI)16	178,000

* Total BSI adjusted to estimate CLABSI (248,678 x 0.37[15]) = 92,011
** Total Pneumonia infections adjusted to estimate VAP (250,205 x 0.21[15]) = 52,543
*** Total UTIs adjusted to estimate CAUTI (561,667 x 0.80[16]) = 449,334

Table 4: The average attributable per patient costs of HAI by selected sites of infection adjusted by 2007 CPIs for all urban consumers and inpatient hospital services

Infection site	Low Estimate of average attributable Costs ($ base year)	High Estimate of average attributable Costs ($ base year)	Low estimate adjusted to 2007 $ using CPI-U	High estimate adjusted to 2007 $ using CPI-U	Adjusted to 2007 $ using CPI for Inpatient Hospital Services	Adjusted to 2007 $ using CPI for Inpatient Hospital Services
SSI	$10,443[18] (2005)	$25,546[3] (2002)	$11,087	$29,443	$11,874	$34,670
CLABSI	$ 5,734[19] (2003)	$22,939[19] (2003)	$ 6,461	$25,849	$ 7,288	$29,156
VAP	$11,897[20] (1999)	$25,072[18] (2005)	$14,806	$27,520	$19,633	$28,508
CAUTI	$ 589[21] (1998)	$ 758[18] (2002)	$ 749	$ 832	$ 862	$ 1,007
CDI	$ 5,042[22] (2003)	$ 7,179[22] (2003)	$ 5,682	$ 8,090	$ 6,408	$ 9,124

Table 5: Aggregate attributable patient hospital costs by site of infection

	# of infections	Range of $ estimates based on 2007 CPI for all urban consumers	Range of $ estimates based on 2007 CPI for Inpatient hospital services	Range of estimate using CPI for all urban consumers (billions)	Range of estimate using CPI for Inpatient hospital services (billions)
SSI	290,485	$11,087 - $29,443	$11,874 - $34,670	$3.22 - $8.55	$3.45 - $10.07
CLABSI	92,011	$ 6,461 - $25,849	$ 7,288- $29,156	$0.59 - $2.38	$0.67 - $2.68
VAP	52,543	$14,806 - $27,520	$19,633 - $28,508	$0.78 - $1.45	$1.03 - $1.50
CAUTI	449,334	$ 749 - $ 832	$ 862 - $ 1,007	$0.34 - $0.37	$0.39 - $0.45
CDI	178,000	$ 5,682 - $ 8,090	$ 6,408 - $ 9,124	$1.01 - $1.44	$1.14 - $1.62

*Example calculation for SSI:

	2007 CPI for all urban consumers:	2007 CPI for hospital inpatient services
Low	290,485 x $11,087 = $3.22 billion	290,485 x $11,874 = $ 3.45 billion
High	290,485 x $29,443 = $8.55 billion	290,485 x $34,670 = $10.07 billion

Table 6: The attributable per patient costs of all HAIs

	Low Estimate of average attributable Costs ($ base year)	High Estimate of average attributable costs ($ base year)	Low estimate adjusted to 2007 $ using CPI-U	High estimate adjusted to 2007 $ using CPI-U	Adjusted to 2007 $ using CPI for Inpatient Hospital Services	Adjusted to 2007 $ using CPI for Inpatient Hospital Services
HAI (all)	$13,973[23] (2001)	$15,275[24] (1998)	$16,359	$19,430	$20,549	$25,903

Table 7: Annual aggregate direct medical hospital patient costs by site of infection

	# of infections	Range of per patient cost estimates based on 2007 CPI-U	Range of per patient cost estimates based on 2007 CPI for Inpatient hospital services	Range of total cost using CPI-U	Range of total cost using CPI for Inpatient hospital services (billions)
All HAI	$1,737,125	$16,359 - $19,430	$20,549 - $25,903	$28.4 - $33.8	$35.7 - $45.0

Table 8: Range of estimated annual direct medical cost of all HAIs adjusted by the preventable proportion of infections

	Range of Estimates (billions $)	20% of infections preventable (billions $)	50% of infections preventable (billions)	70% of infections preventable (billions)
2007 CPI-U	$28.4 - $33.8	$5.7 - $6.8	$14.2 - $16.9	$19.9 - $23.7
2007 CPI hospital inpatient services	$35.7 - $45.0	$7.1 - $9.0	$17.9 - $22.5	$25.0 - $31.5