Major article

Statewide costs of health care-associated infections: Estimates for acute care hospitals in North Carolina

Deverick J. Anderson MD, MPH [a,*], Deborah G. Pyatt BA [b], David J. Weber MD, MPH [b,c],
William A. Rutala PhD, MPH [b,c], and the North Carolina Department of Public Health HAI Advisory Group

[a] Division of Infectious Diseases, Department of Medicine, Duke University School of Medicine, Durham, NC
[b] NC Statewide Program for Infection Control and Epidemiology, UNC School of Medicine, Chapel Hill, NC
[c] Department of Hospital Epidemiology, University of North Carolina Health System, Chapel Hill, NC

Key Words:
Surveillance
Financial analysis
Statewide quality improvement

Background: State-specific, health care-associated infection (HAI) cost estimates have not been calculated to guide Department of Public Health efforts and investments.
Methods: We completed a cost identification study by conducting a survey of 117 acute care hospitals in NC to collect surveillance data on patient-days, device-days, and surgical procedures during 1 year. We then calculated expected rates and direct hospital costs of surgical site infections (SSI), *Clostridium difficile* infection, and 3 selected device-related HAIs for hospitals and the entire state using reference data sets such as the National Healthcare Safety Network.
Results: In total, 67 (53%) hospitals responded to the survey. The median bed size of respondent hospitals was 140 (interquartile range, 66-350). A "standard" NC hospital diagnosed approximately 100 HAI each year with estimated costs of $985,000 to $2.7 million. The most common HAI was SSI (73%). Costs related to SSI accounted for 87% to 91% of overall costs. In total, the overall direct annual cost of these 5 selected HAIs was estimated to be between $124.1 and $347.8 million in 2009 for the state of NC.
Conclusion: Using conservative estimates, HAI led to costs of more than $100 million in acute care hospitals in the state of NC in 2009. The majority of costs were due to SSI.

Health care-associated infections (HAI) lead to devastating outcomes for patients and substantial costs to the US health care system. In total, HAI lead to as many as 99,000 deaths and costs of more than $30 billion each year in the United States.[1,2]

This enormous burden of morbidity and mortality has caused the public, regulatory agencies, and payers to focus on ways to reduce the consequences and costs of these infections. As a result, HAI and, more specifically, hospitals' performances related to prevention of HAI are subject to public reporting requirements in many states.[3] For example, 29 states are now required to report HAI data to the National Healthcare Safety Network (NHSN) by law.[4] Similarly, Centers for Medicare and Medicaid Services (CMS) no longer provides payment for infection because of a central venous catheter and catheter-associated urinary tract infections acquired during hospitalization.[5] These "pay-for-performance" rules and other financial incentives will likely increase in breadth and scope as private insurers follow suit and as CMS expands the list HAI for which reimbursement is prohibited.

Given these growing concerns about HAI, the US Department of Health and Human Services developed an Action Plan to Prevent Healthcare-Associated Infections (HHS Action Plan) that included specific recommendations for surveillance, research, communication, and metrics for measuring progress toward national goals.[6] Federal funding became available in 2009 for states to carry out the HHS Action Plan through the American Recovery and Reinvestment

Act (P.L. 111-15).[7] States receiving these funds were required to devise statewide plans for the creation and implementation of interventions designed to prevent HAI and to develop surveillance systems to monitor HAI. To date, however, state-specific HAI cost estimates have not been calculated to guide these efforts.

North Carolina (NC), the 10th most populous state in the United States, is home to 9.6 million people and includes metropolitan and rural areas, several prominent industries, universities, and natural areas.[8] The NC Department of Public Health received American Recovery and Reinvestment Act funds in 2009 to prevent HAI in acute care hospitals in NC. The Department of Public Health in turn formed an HAI Prevention Advisory Panel to determine the methods and identify potential targets for interventions to decrease the incidence of HAI in NC. A subcommittee was created to determine the cost impact of HAI on the state of NC to aid development of a long-term strategy for HAI prevention that included investment by the state legislature. The main goal of this subcommittee was to calculate the direct costs of selected HAI for acute care hospitals in NC and, subsequently, the state of NC.

METHODS

Survey of North Carolina hospitals

A survey was sent to 117 of the 126 acute care hospitals (median bed size, 109.5; interquartile range [IQR], 50-204, including 3 long-term care facilities) in NC in June 2010. These 117 hospitals were selected because of their prior participation in the NC Statewide Program for Infection Control and Epidemiology. Hospitals were asked to provide data for calendar year 2009 for the following variables: licensed bed size, patient-days, ventilator-days, central line-days, urinary catheter-days, number of surgical procedures, number of intensive care units (ICU), type of ICU, and number of infection preventionists. In addition, hospitals were requested to provide device-days in their ICU(s) and device-days for their entire hospital (including the device-days from the ICU(s)). Similarly, hospitals were asked to differentiate between surgical procedures performed in inpatient and outpatient settings. A second survey was sent to nonresponders in July 2010. Survey responses were averaged to determine a "standard" NC acute care hospital. Hospital-specific bed size data for nonresponders were obtained from the American Hospital Association.[9]

Estimates for rates of HAI

Data published by the NHSN[10] were used to determine mean hospital-specific rates for the following infections: central line-associated bloodstream infection (CLABSI), ventilator-associated pneumonia (VAP), catheter-associated urinary tract infection (CA-UTI), and surgical site infection (SSI). NHSN publishes data separately for different types of locations, such as ICU type, non-ICU ward type, and specialty care locations (eg, 16 distinct ICU types and 20 distinct non-ICU ward types for CLABSI); thus, a weighted-mean rate was calculated for each type of infection based on the number of device-days reported to NHSN for each location. Data published by the Duke Infection Control Outreach Network (DICON) were used to determine the average rate of *Clostridium difficile* infections (CDI) per hospital.[11]

Estimates for cost of HAIs

Minimum and maximum cost estimates were used for each of the selected HAI, based on published data from the Centers for Disease Control and Prevention (CDC) (Table 1).[2] These estimates represent direct costs for each HAI in 2007 US dollars based on the

Table 1
Direct cost estimates for selected HAIs in 2007 US dollars[3]

Type of infection	Minimum cost	Maximum cost
Central line-associated bloodstream infection	$7,288	$29,156
Ventilator-associated pneumonia	$19,633	$28,508
Catheter-associated urinary tract infection	$862	$1,007
Surgical site infection	$11,874	$34,670
Clostridium difficile infection	$6,408	$9,124

Consumer Price Index for inpatient hospital services. These estimates were based on 3 key assumptions: (1) all NC hospitals were assumed to have HAI rates equal to NHSN means, (2) costs were assumed to be equal across all hospitals, and (3) hospitals were assumed to have the same HAI rate by standardization.

Costs of HAI in North Carolina hospitals

Numbers of each of the selected HAI were calculated for the "standard" NC hospital by applying the weighted-mean rates for each of the HAI from NHSN to the medians of the surveillance data from the survey of hospitals. For example, if the "standard" NC hospital accrued 2,000 central line-days each year and the weighted-mean rate for CLABSI based on NHSN data was 2.55 CLABSIs/1,000 central line-days, then the "standard" NC hospital would expect to have 5.1 CLABSI each year.

These estimates were then multiplied by the minimum and maximum costs of each specific type of HAI to determine the annual costs for each infection for the "standard" NC hospital. The minimum and maximum costs for each type of infection were summed to determine total minimum and maximum cost estimates of HAI for the "standard" NC hospital. These minimum and maximum cost estimates were then multiplied by 126 (ie, the number of acute care hospitals in NC) to determine minimum and maximum statewide cost estimates for HAIs for NC.

Subanalysis and sensitivity analysis

A subanalysis was performed to determine costs related to 3 specific categories of infection: device-related infections in the ICU, SSI following inpatient surgical procedures, and hospital-wide CDI. These categories were selected because published estimates for cost are most specific to these categories. This approach overcomes the limitation of extrapolating costs from a specific area to a broader area. For example, published data from CLABSIs in the ICU may not be accurate for CLABSIs that occur outside the ICU or costs from SSIs diagnosed following inpatient procedures may not be accurate for outpatient surgical procedures.

Two additional sensitivity analyses were performed. First, cost estimates were calculated after limiting the analysis to respondents only. That is, nonrespondent hospitals were assumed to have zero HAI; thus, these estimates represent the most conservative estimates possible from our models. Second, we recalculated costs for the state by using hospital-specific data provided by respondents, instead of calculating costs for a "standard" hospital. This model was created by first applying the weighted-mean rates for each of the HAIs from NHSN to the actual surveillance data from respondents to calculate the estimated number of each specific HAI for each respondent hospital. Total numbers of each of the HAI were then calculated by summing the results for each respondent hospital. These estimates were then multiplied by the minimum and maximum costs of each specific type of HAI to determine the annual costs for each infection for respondent hospitals. After calculating the total number of beds in the 126 acute care hospitals, we calculated the number of beds represented by respondents for each of the HAI (eg, 62 [49%] hospitals responded with surgical

procedure data, but these 62 hospitals represented 61% of beds in NC). The minimum and maximum cost estimates for each HAI were then divided by the proportion of beds represented to determine minimum and maximum statewide cost estimates for each HAI (eg, statewide cost of SSI = total cost at respondent hospitals/0.61). Costs for each HAI were then summed to determine the minimum and maximum statewide cost estimates for the state of NC.

Statistical analysis

Standard descriptive statistics were used to calculate means, medians, and IQR. Medians were compared using the Wilcoxon rank-sums test. Statistical testing was performed using SAS v9.2 (SAS Institute, Cary, NC).

RESULTS

In total, 67 (53%) hospitals responded to the survey. The median bed size of respondent hospitals was 140 (IQR, 66-350). Hospitals that responded to the survey were generally larger than non-responding hospitals. The median bed size for hospitals that did not respond was 92 (IQR, 43-131; $P = .009$ compared with hospitals that responded). The median number of infection preventionists at each respondent hospital was 1 full-time equivalent (IQR, 1-2). In general, hospitals were more likely to provide ICU-specific device data than hospital-wide data (Table 2).

Respondent hospitals in NC were similar to the hospitals that reported to NHSN based on bed size. For example, hospitals in NC that responded to the survey and hospitals that report to NHSN had the same proportion of hospitals with bed size less than 200 (63% of NC hospitals vs 64% of NHSN hospitals).

The "standard" NC hospital detects approximately 100 HAIs each year (Table 3). The most common HAI was SSI (73% of HAIs). Overall, the cost of the selected HAI in the "standard" NC hospital was between $985,000 and $2.7 million annually (Table 3). Costs related to SSI accounted for 87% to 91% of overall costs. After restricting the calculation to costs in the ICUs for device-related infections, SSIs following inpatient surgical procedures, and hospital-wide CDI, the cost of HAI in the "standard" NC hospital was between $436,000 and $1.1 million annually.

These estimates for direct costs due to HAI for the "standard" NC hospital were then applied to all 126 acute care hospitals in NC. In total, the overall direct annual cost of these 5 selected HAI for the state of NC was estimated to be between $124.1 and $347.8 million. When our calculations were restricted to costs in the ICU for device-related infections, SSIs following inpatient surgical procedures, and hospital-wide CDI, the total overall direct annual cost of these 5 selected HAI for the state of North Carolina was estimated to be between $54.9 and $144.3 million (Table 4).

Finally, 2 additional sensitivity analyses were performed. First, after limiting costs to only respondent hospitals, the overall direct annual cost of these 5 selected HAI for the state of NC was estimated to be between $66.0 and $184.9 million. Second, we tested the assumption that calculating rates and costs for a "standard" NC hospital was an appropriate approach by creating a model that relied only on surveillance data provided by respondents. Using this approach, the overall direct annual cost of the 5 selected HAI for the state of NC was estimated to be between $224 and $617.7 million.

DISCUSSION

Our study is the first to provide statewide estimates for the direct costs of HAI. Using estimates published by the CDC and surveillance data, we conservatively estimate that HAI cost the

Table 2
Summary of surveillance data from acute care hospitals in North Carolina

Variable	Number of respondents, n (%)	Median	IQR
Patient-days	66 (99)	24,980.5	(10,047-52,972)
Central line-days			
ICU	56 (84)	1,031.5	(256.6-2,837.5)
Hospital wide	39 (58)	1,952	(366-6,738)
Ventilator-days			
ICU	58 (87)	709	(184-2,051)
Hospital wide	59 (88)	646	(168-2,051)
Urinary catheter-days			
ICU	49 (73)	2,011	(949-3,925)
Hospital wide	34 (51)	2,895	(1,239-9,839)
Surgical procedures (total)	62 (93)	3,752	(2,113-9,637)
Inpatient	45 (67)	1,380	(400-3,938)
Outpatient	47 (70)	3,931	(1,378-6,557)

ICU, intensive care unit; IQR, interquartile range.

state of NC greater than $100 million each year. These estimates may help departments of public health in other states and other advocates of infection prevention determine and validate potential investments in HAI prevention in their state or region. Finally, our methods can potentially be reproduced for other states to calculate their state-specific HAI costs.

Of note, SSI led to the highest overall cost, accounting for approximately 90% of the costs of HAIs in the state of NC. Thus, our analysis suggests that initiatives to reduce the costs of HAI should focus primarily on preventing SSIs. Assuring knowledge of and compliance with national guidelines for the prevention of SSI would be a first step,[12] but novel interventions are needed as well.

Our cost estimates for HAI have wide ranges, reflecting the difficulties in studying and publishing data on cost of HAI. Regardless of the actual amount or range, all studies that we are familiar with have demonstrated that HAI are expensive. In addition to lost opportunity costs for hospitals, HAI lead to costs to society including early deaths and disability.[1,13-15] Thus, our data provide further incentives for all hospitals and states to invest in HAI prevention programs. This incentive is particularly relevant because most hospitals have progressively received less reimbursement for patients with several types of HAI. Indeed, this trend in declining reimbursement is likely to continue or accelerate as federal agencies and payers seek new ways to promote quality of care and to reduce costs. For example, CMS will soon initiate programs that promote "value-based purchasing programs" in which hospitals with higher rates of HAI will receive less support from CMS than hospitals with low rates. These programs will reduce margins even further for many hospitals.[16]

Our estimates likely underestimate the true cost of HAI in the state of NC for several reasons. First, respondent hospitals were generally larger than nonresponding hospitals. Rates of some HAI and adverse outcomes such as SSI and VAP are higher in smaller community hospitals than medium-sized community hospitals[17-19]; thus, our rate estimates and subsequently our cost estimates may be low, particularly because the majority of infections and cost were because of SSI. Second, these estimates were calculated using previously published estimates of direct costs of HAI and do not include indirect costs and subsequent costs to society from lost wage and production.[20] Third, these estimates only include 5 types of HAIs. These HAIs constitute only 50% of HAIs[21]; costs of other HAI (eg, hospital-acquired pneumonia in the absence of the ventilator) were not included. Fourth, the differential increase in costs because of HAI caused by multidrug-resistant pathogens was not included. Finally, our sensitivity analysis using actual surveillance data instead of extrapolating from a "standard" NC hospital led to higher cost estimates.

Table 3
Surveillance, rate, health care-associated infection, and cost estimates for the "standard" North Carolina hospital

HAI	Median exposure-days* (IQR)	Weighted mean rate from the NHSN*	Estimated number of infections	Cost estimates from the CDC		Estimated direct costs for standard NC hospital	
				Minimum	Maximum	Minimum	Maximum
CLABSI	1,952 (366-6,738)	1.93	3.8	$7,288	$29,156	$27,513	$110,069
VAP	709 (168-2,051)	3.14	2.0	$19,633	$28,508	$39,799	$57,780
CAUTI	2,895 (1,239-9,839)	4.79	13.9	$862	$1,007	$11,951	$13,961
SSI	3,931 (2,113-9,637)	1.93	72.5	$11,874	$34,670	$861,176	$2,514,482
CDI	24,980.5 (10,047-52,972)	0.28	7.0	$6,408	$9,124	$44,821	$63,818

CAUTI, catheter-associated pneumonia; *CDC*, Centers for Disease Control and Prevention; *CDI*, *Clostridium difficile* infection; *CLABSI*, central line-associated bloodstream infection; *NC*, North Carolina; *NHSN*, National Healthcare Safety Network; *SSI*, surgical site infection; *VAP*, ventilator-associated pneumonia.
*Exposure-days were determined by surveying hospitals in NC. Rate denominators are equivalent to exposure-days: CLABSI/1,000 central line-days; VAP/1,000 ventilator-days; CAUTI/1,000 urinary catheter-days; SSI/100 surgical procedures; CDI/1,000 patient-days.

Table 4
Surveillance, rate, health care-associated infection, and cost estimates for the "standard" North Carolina hospital limited to device-related infections in intensive care units, surgical site infections following inpatient surgical procedures, and *C difficile* diagnosed as an inpatient

HAI	Median exposure-days* (IQR)	Weighted mean rate from the NHSN*	Estimated number of infections	Cost estimates from the CDC		Estimated direct costs for standard NC hospital	
				Minimum	Maximum	Minimum	Maximum
CLABSI	1,031.5 (256.5-2,837.5)	2.06	2.1	$7,288	$29,156	$15,486.20	$61,953.29
VAP	709 (184-2,051)	3.19	2.3	$19,633	$28,508	$44,431.99	$64,517.25
CAUTI	646 (168-3,925)	4.07	8.2	$862	$1,007	$7,060.47	$8,248.14
SSI	1,380 (400-3,938)	1.98	27	$11,874	$34,670	$324,117.45	$946,366.19
CDI	24,980.5 (10,047-52,972)	0.28	7.0	$6,408	$9,124	$44,821	$63,818

CAUTI, catheter-associated pneumonia; *CDC*, Centers for Disease Control and Prevention; *CDI*, *Clostridium difficile* infection; *CLABSI*, central line-associated bloodstream infection; *NC*, North Carolina; *NHSN*, National Healthcare Safety Network; *SSI*, surgical site infection; *VAP*, ventilator-associated pneumonia.
*Exposure-days were determined by surveying hospitals in NC. Rate denominators are equivalent to exposure-days: CLABSI/1,000 central line-days; VAP/1,000 ventilator-days; CAUTI/1,000 urinary catheter-days; SSI/100 surgical procedures; CDI/1,000 patient-days.

Although likely underestimations, our estimates and cost models need to be interpreted with caution. In fact, our goal was not necessarily to calculate a specific value for the overall cost of HAI but, instead, to create general estimates to help guide policy decisions and potential investment. HAI outcome data (as reported to the NHSN and as obtained by hospitals across the United States) likely suffers from "surveillance bias."[22,23] Thus, surveillance data likely underestimate the true number of HAI occurring in hospitals in NC. In addition, cost considerations depend a great deal on perspective, including hospital (lost opportunity), patient (outcomes), and society (lost wage and production). Finally, not all HAI are preventable. In fact, a recent report by Umscheid et al stated that as many as one-third of all cases of CLABSI and CAUTI and almost half of all cases of VAP and SSI were not preventable.[24] Thus, our estimates do not represent the total amount of money that could potentially be saved through enhanced infection prevention.

Our study has other limitations. First, the biggest limitation of our study is the 53% response rate. Thus, our estimates may not accurately represent infection rates at nonresponders. On the other hand, we believe that the size difference between respondent and nonresponding hospitals would lead to an under-estimation of rates and costs, as described above. Second, the cost estimates published by the CDC may suffer from the same limitations of the studies used to create the estimates. More specifically, these studies may have had suboptimal or incomplete matching.[25] In addition, propensity scores were not used to match cases and controls.[26] Finally, our estimates were not adjusted for inflation.

In summary, our study provides an estimate of the total cost of HAI for the state of NC each year. To our knowledge, no other groups have utilized state surveillance estimates to estimate state costs. The cost of HAI to hospitals in NC is staggering high, and SSI costs account for the large majority of these costs. Our efforts to estimate the costs of HAI in a single state should be viewed as a small but necessary step in helping other states define the nature of the problems facing their individual hospitals. Our estimates can also be used to formulate and justify the next critical steps for improving the care of hospitalized patients: designing, promoting, and maintaining new and better programs that actually prevent HAI. Indeed, it is necessary to define and understand the economic costs of HAI before mobilizing the resources and incentives to reduce the incidence of infections that generate these costs. Finally, costs can in turn be one of several outcomes that is used to measure the effectiveness of prevention efforts and to justify their costs.

Acknowledgment

References

1. Klevens RM, Edwards JR, Richards CL Jr, Horan TC, Gaynes RP, Pollock DA, Cardo DM. Estimating health care-associated infections and deaths in US hospitals, 2002. Public Health Rep 2007;122:160-6.
2. Scott RD. The direct medical costs of health care-associated Infections in US hospitals and the benefits of prevention. Atlanta [GA]: Division of Healthcare Quality Promotion National Center for Preparedness, Detection, and Control of Infectious Diseases Coordinating Center for Infectious Diseases Centers for Disease Control and Prevention; 2009.
3. Hospital Compare. 2012. Available from: http://hospitalcompare.hhs.gov/. Accessed May 1, 2012.
4. State-based HAI prevention. 2012. Available from: http://www.cdc.gov/hai/stateplans/required-to-report-hai-NHSN.html. Accessed May 1, 2012.
5. Centers for Medicare and Medicaid Services HHS. Medicare program; changes to the hospital inpatient prospective payment systems and fiscal year 2008 rates. Federal Register 2007;72:47129-8175.
6. National Action Plan to Prevent Healthcare-Associated Infections: Roadmap to Elimination. US Department of Health and Human Services. Available from: http://www.hhs.gov/ash/initiatives/hai/actionplan; 2012. Accessed May 1, 2012.
7. American Recovery and Reinvestment Act of 2009. 2009. Available from: http://thomas.loc.gov/cgi-bin/toGPObsspubliclaws/http://www.gpo.gov/fdsys/pkg/PLAW-111publ5/pdf/PLAW-111publ5.pdf. Page 180. Accessed May 1, 2012.
8. State and county QuickFacts-North Carolina. 2012. Available from: http://quickfacts.census.gov/qfd/states/37000.html. Accessed May 1, 2012.
9. Fast facts on US hospitals. 2007. Available from: http://www.aha.org/aha/resource-center/Statistics-and-Studies/fast-facts.html. Accessed July 17, 2007.

10. Edwards JR, Peterson KD, Mu Y, Banerjee S, Allen-Bridson K, Morrell G, et al. National Healthcare Safety Network (NHSN) report: data summary for 2006 through 2008, issued December 2009. Am J Infect Control 2009;37:783-805.
11. Miller BA, Chen LF, Sexton DJ, Anderson DJ. Comparison of the burdens of hospital-onset, healthcare facility-associated *Clostridium difficile* infection and of healthcare-associated infection due to methicillin-resistant *Staphylococcus aureus* in community hospitals. Infect Control Hosp Epidemiol 2011;32:387-90.
12. Anderson DJ, Kaye KS, Classen D, Arias KM, Podgorny K, Burstin H, et al. Strategies to prevent surgical site infections in acute care hospitals. Infect Control Hosp Epidemiol 2008;29(Suppl 1):S51-61.
13. Cosgrove SE, Qi Y, Kaye KS, Harbarth S, Karchmer AW, Carmeli Y. The impact of methicillin resistance in *Staphylococcus aureus* bacteremia on patient outcomes: mortality, length of stay, and hospital charges. Infect Control Hosp Epidemiol 2005;26:166-74.
14. Jarvis WR. Selected aspects of the socioeconomic impact of nosocomial infections: morbidity, mortality, cost, and prevention. Infect Control Hosp Epidemiol 1996;17:552-7.
15. 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;20:725-30.
16. Thompson CA. CMS reveals Medicare's value-based purchasing program for hospitals. Am J Health Syst Pharm 2011;68:1062-71.
17. Anderson DJ, Hartwig MG, Pappas T, Sexton DJ, Kanafani ZA, Auten G, Kaye KS. Surgical volume and the risk of surgical site infection in community hospitals: size matters. Ann Surg 2008;247:343-9.
18. Kahn JM, Goss CH, Heagerty PJ, Kramer AA, O'Brien CR, Rubenfeld GD. Hospital volume and the outcomes of mechanical ventilation. N Engl J Med 2006;355:41-50.
19. Lee MS, Walker V, Chen LF, Sexton DJ, Anderson DJ. The epidemiology of ventilator associated pneumonia (VAP) in a network of community hospitals: a prospective, multicenter study. ID Week 2012. Abstract No. 1104. San Diego, CA. 2012.
20. Anderson DJ, Kirkland KB, Kaye KS, Thacker PA, Kanafani ZA, Auten G, Sexton DJ. Underresourced hospital infection control and prevention programs: penny wise, pound foolish? Infect Control Hosp Epidemiol 2007;28:767-73.
21. Weber DJ, Sickbert-Bennett EE, Brown V, Rutala WA. Completeness of surveillance data reported by the National Healthcare Safety Network: an analysis of healthcare-associated infections ascertained in a tertiary care hospital, 2010. Infect Control Hosp Epidemiol 2012;33:94-6.
22. Haut ER, Pronovost PJ. Surveillance bias in outcomes reporting. JAMA 2011; 305:2462-3.
23. Lin MY, Bonten MJ. The dilemma of assessment bias in infection control research. Clin Infect Dis 2012;54:1342-7.
24. Umscheid CA, Mitchell MD, Doshi JA, Agarwal R, Williams K, Brennan PJ. Estimating the proportion of healthcare-associated infections that are reasonably preventable and the related mortality and costs. Infect Control Hosp Epidemiol 2011;32:101-4.
25. 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;25:481-8.
26. Ben-David D, Novikov I, Mermel LA. Are there differences in hospital cost between patients with nosocomial methicillin-resistant *Staphylococcus aureus* bloodstream infection and those with methicillin-susceptible *S. aureus* bloodstream infection? Infect Control Hosp Epidemiol 2009;30: 453-60.