ORIGINAL ARTICLE

Incidence of and Risk Factors for Nosocomial Bloodstream Infections in Adults in the United States, 2003

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BACKGROUND. Although many studies have examined nosocomial bloodstream infection (BSI), US national estimates of incidence and case-fatality rates have seldom been reported.

OBJECTIVE. The purposes of this study were to generate US national estimates of the incidence and severity of nosocomial BSI and to identify risk factors for nosocomial BSI among adults hospitalized in the United States on the basis of a national probability sample.

METHODS. This cross-sectional study used the US Nationwide Inpatient Sample for the year 2003 to estimate the incidence and case-fatality rate associated with nosocomial BSI in the total US population. Cases of nosocomial BSI were defined by using 1 or more *International Classification of Diseases, 9th Revision, Clinical Modification* codes in the secondary field(s) that corresponded to BSIs that occurred at least 48 hours after admission. The comparison group consisted of all patients without BSI codes in their NIS records. Weighted data were used to generate US national estimates of nosocomial BSIs. Logistic regression was used to identify independent risk factors for nosocomial BSI.

RESULTS. The US national estimated incidence of nosocomial BSI was 21.6 cases per 1,000 admissions, while the estimated case-fatality rate was 20.6%. Seven of the 10 leading causes of hospital admissions associated with nosocomial BSI were infection related. We estimate that 541,081 patients would have acquired a nosocomial BSI in 2003, and of these, 111,427 would have died. The final multivariate model consisted of the following risk factors: central venous catheter use (odds ratio [OR], 4.76), other infections (OR, 4.61), receipt of mechanical ventilation (OR, 4.97), trauma (OR, 1.98), hemodialysis (OR, 4.83), and malnutrition (OR, 2.50). The total maximum rescaled R^2 was 0.22.

CONCLUSIONS. The Nationwide Inpatient Sample was useful for estimating national incidence and case-fatality rates, as well as examining independent predictors of nosocomial BSI.

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Nosocomial bloodstream infection (BSI), the most severe form of healthcare-associated infection,[1] is associated with substantial morbidity and mortality,[2,3] as well as increased length of stay and healthcare costs.[4-7] The reported incidence and case-fatality rates of nosocomial BSI vary, especially between intensive care unit (ICU) and non-ICU populations. Incidence ranged from 0.6 cases per 100 admissions across all units[4] to 9.7 cases per 100 ICU admissions.[8] Case-fatality rates ranged from a low of 21.1%[9] in a non-ICU population to a high of 69% in an ICU population.[7]

Male sex occasionally has been shown to increase the risk of nosocomial BSI,[10-13] but this result has not occurred consistently.[8,9,14] However, female sex has been associated with an increased risk of mortality.[15] Increased age has been shown to be a significant risk factor for nosocomial BSI in many[8,12,16,17] but not all studies.[18] Other risk factors for nosocomial BSI include the number of preexisting comorbidities,[19,20] severity of illness,[9,21] and the presence of heart disease,[11,22] cancer,[11,13,18,23] diabetes mellitus,[11,24] chronic pulmonary disease,[11,17] alcoholism,[11] central venous catheter (CVC),[18,25,26] peripheral intravenous catheter,[27] ventilator-associated pneumonia,[17] urinary tract infection, preexisting infection,[28] multiple trauma,[12] burns,[12] anemia,[25] or malnutrition,[29,30] the use of immunosuppressive drugs[13,17,31] or H_2 blockers,[7] transfusion of multiple units of blood or blood products,[18,32] receipt of total parenteral nutrition,[33,34] receipt of hemodialysis,[11,31,35] presence of nasogastric tubes,[7] tracheostomies,[17] receipt of mechanical ventilation,[7,24] and surgical or other invasive procedures.[7,18,28] Most published studies have been limited to nonprobability samples from 1 or a few tertiary care centers. The purposes of this study were to generate US national estimates of the incidence and severity of nosocomial BSI and to identify risk factors for nosocomial BSI among adults hospitalized in the United States on the basis of a national probability sample.

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METHODS

Data Source

Our cross-sectional study is based on the US Nationwide Inpatient Sample (NIS) for the year 2003. The NIS data sets are publically available and, therefore, lack the individual identifiers that would be used to determine what proportion of individuals had more than 1 nosocomial BSI event during the study year. We therefore make the assumption that having more than 1 nosocomial BSI event during the study year is rare and would have a negligible effect on the incidence and case-fatality rate estimates.

The NIS is reported to be the largest all-payer inpatient care database that is publicly available in the United States. This national probability data set,[36] which used a sample consisting of all inpatient stays that occurred in 20% of US community hospitals, provides information on approximately 8 million inpatient stays from 994 hospitals in 37 states.[37] When weighted analyses are reported, the findings represent the target universe of 4,836 hospitals in the United States that match the definition of community hospitals used by the American Hospital Association.[36] The analysis was limited to cases that occurred in patients 18 years of age or older. Missing demographic data were as follows: sex, less than 0.2% (8,247/5,424,343); race, 26.2% (1,419,326/5,424,343); and type of admission, 10.4% (563,823/5,424,343). Patient records that were missing these variables were omitted from the analysis. Data on the type of organism that caused the infection were missing in 73,490 of the 113,436 nosocomial BSI cases (64.8%) and 37,213 of the community-acquired BSI cases (51.4%).

Case Definitions and Final Sample

Cases of community-acquired BSI were defined as those that received a primary diagnosis based on a select set of *International Classification of Diseases, 9th Revision, Clinical Modification* (*ICD-9-CM*) codes (Appendix, Table A) at the time of admission or within the first 48 hours in the hospital (Figure). Cases of nosocomial BSI were defined as those that received 1 or more of the same *ICD-9-CM* codes (Appendix, Table A) as a secondary diagnosis 48 hours or longer after admission. This definition was based on the Centers for Disease Control and Prevention (CDC)[38] definition and has been widely used in other studies.[5,39-41] The *ICD-9-CM* codes were identified on the basis of a literature review and through searching the online and hard copy manuals.[42,43] The use of *ICD-9-CM* for identifying BSI and other related conditions is considered a valid method and has been widely employed in other studies.[44-47]

After the inclusion criteria were applied, the final sample consisted of 5,424,343 adults, of whom 113,436 had a diagnosis that met the nosocomial BSI case definition. The uninfected comparison group of 5,238,519 patients excluded those with nosocomial or community-acquired BSI.

Data Analysis Procedures

Descriptive and bivariate analyses. Analyses were conducted with SAS-PC, version 9.1 (SAS Institute). Frequencies, percentages, means, and their standard deviations were used to describe the sample. After the frequencies were defined with SAS, standard formulas[48] were used to calculate the incidence and case-fatality rates of nosocomial BSI. Individuals whose records were missing data (<5%) for the variables of interest were excluded from the final analysis. The sampling design and weights included in the data set allow statistically valid calculation of national-level estimates[36,49] and were used as described by Houchens and Elixhauser.[49] The SAS weighting procedure was used to compute estimated population means and their standard errors.

The risk factors available for analysis consisted of age, sex, admission and secondary diagnoses, number of comorbidities and procedures, and presence of existing infections, trauma, anemia, malnutrition, alcoholism, smoking, blood transfusion, total parenteral nutrition, invasive procedures (eg, lumbar puncture, angioplasty, bronchoscopy, urinary catheter), CVC use, peripheral arterial or venous catheter use, hemodialysis, nasogastric tube, tracheostomy, and mechanical ventilation. Risk factors were determined by searching both the diagnosis and the procedural fields. These fields were used together because some risk factor definitions include both diagnostic and procedural codes. For example, mechanical ventilation was determined to be present if a diagnosis code that indicates dependence on a respirator was present and/or if a procedural code that indicates mechanical ventilation, such as insertion of an endotracheal tube, was present. A list of these diagnoses and procedures was reviewed by 2 expert clinicians, who judged its comprehensiveness and appropriateness for the purposes of this study. Any disagreements were resolved through consensus.

Risk factors were dichotomized for ease of interpretation, and cross-tabulations were computed. The decision to dichotomize age with the cutoff of 65 years and older versus 18–64 years was based on reports that showed less accessibility of healthcare services for adults younger than 65 years of age[3] and on our desire to be consistent with cutoffs used in previous studies.[7,14] Mantel-Haenszel odds ratios (ORs) were used to determine whether interaction occurred. As a result of the very large sample size, the Breslow-Day test of the homogeneity of the OR almost uniformly was highly statistically significant but not meaningfully different. Consequently, interaction was determined on the basis of whether the OR in 1 stratum was protective (<1) and the other a risk factor (>1). The significance level for ORs was set at α less than or equal to .05 (95% confidence interval). In the absence of interaction, age- and sex-adjusted ORs were computed. However, no confounding by these factors was evident, and therefore, we report univariate ORs.

Logistic regression. Stepwise logistic regression was used with risk factors selected on the basis of previous studies and

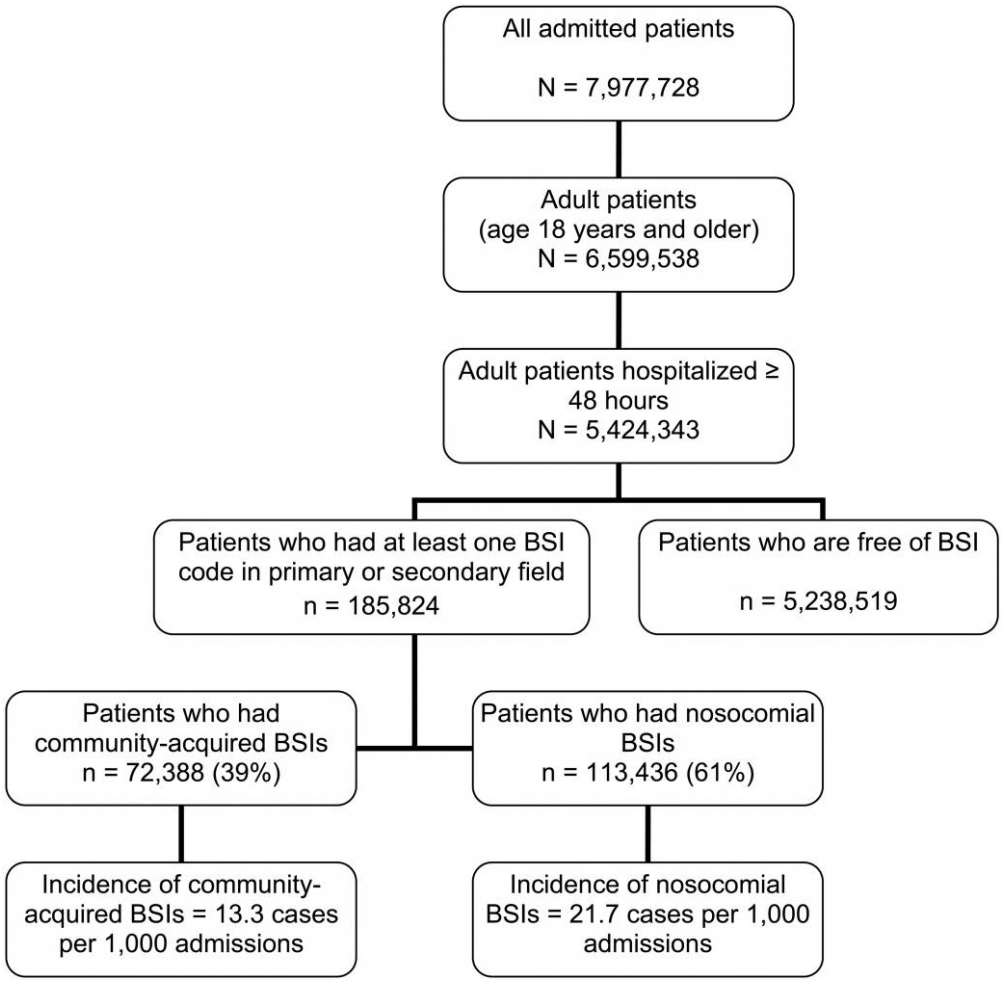

FIGURE. Flow chart showing the results of applying case-finding definitions to the Nationwide Inpatient Sample, 2003 (unweighted data). BSI, bloodstream infection.

in which the univariate ORs were at least 2.0. Because CVC use and peripheral venous catheter use were collinear ($r = 0.9$), we used only CVC use in the multivariate models. We examined the R^2 with and without age (dichotomized) and sex in the models. Age and sex were excluded from the final model, as they did not contribute to the R^2.

RESULTS

Description of the Sample

There were 7,977,728 admissions in the NIS in 2003 (Figure). The majority of eligible patients admitted were women (3,375,190 of 5,416,096 patients whose sex was recorded [62.3%]). Emergency admissions were the most frequent type of admission (48.4%), followed by elective admissions (29.3%) (characteristics of infected and uninfected patients are presented in Table 1). Patients with a diagnosis of nosocomial or community-acquired BSI were older than uninfected patients. A greater proportion of men were hospitalized for nosocomial BSI than community-acquired BSI. Most of the nosocomial BSI patients were admitted on an emergency basis, but only 45 (0.04%) were admitted as a result of trauma. Patients with nosocomial BSI underwent, on average, more procedures than other patients and had a greater number of comorbidities. Of the nosocomial BSI cases with culture results recorded, only 2,518 of 40,403 (6.2%) were polymicrobial infections.

As noted previously, microorganisms were substantially underreported. The most prevalent specific causative agent noted in the data set for nosocomial BSI was *Staphylococcus aureus* (12,983/113,436 cases [11.4%]). In contrast, *Escherichia coli* was the most prevalent agent among patients with a diagnosis of community-acquired BSI (9,831/72,388 cases [13.6%]).

For nosocomial BSI, the population (weighted) estimated incidence was 21.6 cases per 1,000 admissions. The population estimated case-fatality rate was 20.6%. These estimates

TABLE 1. Characteristics of Unweighted Sample, Nationwide Inpatient Sample, 2003

Variable	Patients with nosocomial BSI (N = 113,436)	Uninfected patients (N = 5,238,519)
Age, years, mean ± SE	64.6 ± 0.268	57.3 ± 0.230
Male sex	56,889 (50.2)	1,951,646 (37.3)
Race or ethnicity	(n = 86,994)	(n = 3,864,560)
White	55,088 (63.3)	2,660,222 (68.8)
Black	16,862 (19.4)	553,215 (14.3)
Hispanic	10,275 (11.8)	453,525 (11.7)
Asian or Pacific Islander	2,535 (2.9)	8,683 (0.2)
Native American	208 (0.2)	7,627 (0.2)
Other	2,026 (2.3)	103,488 (2.7)
Type of admission	(n = 100,323)	(n = 4,696,178)
Emergency	66,456 (66.2)	2,237,229 (47.6)
Urgent	20,026 (20.0)	1,077,561 (22.9)
Elective	13,712 (13.7)	1,373,563 (29.2)
Trauma center	45 (0.04)	2,584 (0.06)
No. of diagnoses, mean ± SE	10.2 ± 0.111	6.2 ± 0.043
No. of procedures, mean ± SE	3.6 ± 0.062	1.6 ± 0.023
LOS, days, mean ± SE	16.0 ± 0.225	5.4 ± 0.036

NOTE. Data are no. (%) unless otherwise indicated. BSI, bloodstream infection; LOS, length of stay; SE, standard error.

were nearly identical to the unweighted sample estimates (Figure). The projected number of patients in the United States who would have acquired a nosocomial BSI in 2003 is 541,081. The projected number of deaths in 2003 attributed to nosocomial BSI was 111,427. For community-acquired BSI, the unweighted incidence was 13.3 cases per 1,000 admissions, while the case-fatality rate was 13.6%.

Risk Factors for Nosocomial BSI

The leading comorbidity group associated with an increased risk of nosocomial BSI was the group with injury or poisoning (Table 2). Other comorbidity groups associated with at least a doubling of risk were the group with metabolic diseases and immunity disorders and the groups with diseases of the blood, nervous and sensory systems, respiratory system, or skin and subcutaneous tissue.

More than 70% of patients with either nosocomial or community-acquired BSI had at least 1 other infection in addition to the BSI (data not shown). In the univariate analyses, multiple factors were associated with an increased risk of nosocomial BSI (Table 2). In particular, the highest risks for nosocomial BSI were associated with mechanical ventilation, CVC use, total parenteral nutrition, peripheral intravenous and arterial lines, other infections, and malnutrition; smaller risks were associated with blood transfusions, trauma, and anemia. Increased age and male sex had small effects (60% and 70%, respectively) on the risk of nosocomial BSI. Neither alcoholism nor cigarette smoking contributed substantially to the model.

The risk factors included in the final model consisted of other infections, trauma, mechanical ventilation, CVC use, hemodialysis, and malnutrition, which met the α criterion of .05, as well as an adjusted OR of 2.0 or greater (Table 3). Forcing age and sex into the model produced a total maximum rescaled R^2 of 0.22. In the final model, 21.7% of the variance was accounted for by the model that excluded age and sex. Finally, hemodialysis and malnutrition were preserved in the final model even though these 2 variables added only 1% to the total maximum rescaled R^2. This decision was made on the basis of the nearly 5-fold increased risk of nosocomial BSI associated with hemodialysis and the 2.5-fold increased risk associated with malnutrition. In summary, the final model consists of the following risk factors: CVC use, other infections, mechanical ventilation, trauma, hemodialysis, and malnutrition. The probability of a nosocomial BSI at the .02 level in this model had a sensitivity of 84% and a specificity of 71%. At this level of sensitivity and specificity, the model was able to predict 71% of nosocomial BSIs cases correctly.

DISCUSSION

Population Estimates

Most of the published studies on the incidence and burden of nosocomial BSI in the United States are based on smaller, nongeneralizable data sources. This study, however, is based on a large and representative sample of US hospitalizations in 2003 so that we could better estimate population incidence

TABLE 2. Unadjusted Odds Ratios for Risk Factors in Patients with Nosocomial Bloodstream Infection (BSI) and in Uninfected Patients, Nationwide Inpatient Sample, 2003

Variable	No. (%) of patients with nosocomial BSI (N = 113,436)	No. (%) of uninfected patients (N = 5,238,519)	Relative risk (95% CI)[a]
Patient factors			
Increased age[b]	62,430 (55.0)	2,253,189 (43.0)	1.6 (1.60–1.64)
Male sex	56,540 (49.9)	3,278,639 (62.7)	1.70 (1.67–1.71)
Other infections	78,188 (68.9)	1,334,551 (25.5)	6.5 (6.4–6.5)
Trauma	60,763 (53.6)	1,548,962 (29.6)	2.7 (2.7–2.8)
Anemia	32,266 (28.4)	864,108 (16.5)	2.0 (2.0–2.1)
Malnutrition	12,127 (10.7)	523519 (2.0)	5.8 (5.7–5.9)
Comorbidities			
Metabolic diseases and immunity disorders	56,255 (49.5)	1,708,765 (32.6)	2.0 (2.0–2.1)
Diseases of blood	15,935 (14.0)	209,708 (4.0)	3.9 (3.8–4.0)
Diseases of nervous system and senses	63,981 (65.4)	1,313,095 (25.0)	3.9 (3.8–3.9)
Diseases of respiratory system	60,312 (53.1)	1,345,828 (25.7)	3.3 (3.2–3.3)
Diseases of genitourinary system	54,930 (48.4)	1,153352 (22.0)	3.3 (3.3–3.4)
Diseases of skin and subcutaneous tissue	22,615 (19.9)	502,748 (9.6)	2.3 (2.3–2.4)
Injury or poisoning	85,503 (75.4)	2,121,563 (40.5)	4.5 (4.4–4.5)
Diagnostic and treatment factors			
Invasive procedures	18,594 (16.4)	502,616 (9.6)	1.8 (1.8–1.9)
Central venous catheter use	38.314 (33.8)	215,032 (4.1)	11.9 (11.8–12.1)
Peripheral arterial line use	4,701 (4.1)	27,835 (0.53)	8.1 (7.8–8.3)
Peripheral intravenous catheter use	36,792 (32.4)	220,462 (4.2)	10.9 (10.8–11.1)
Hemodialysis	3,769 (3.3)	34,096 (0.7)	5.2 (5.1–5.4)
Nasogastric tube use	92 (0.08)	2,105 (0.04)	2.0 (1.6–2.4)
Tracheostomy	11,389 (10.0)	295,923 (5.7)	1.9 (1.8–1.9)
Receipt of mechanical ventilation	28,544 (25.2)	122,235 (2.3)	14.1 (13.9–14.3)
Receipt of blood transfusion	24,381 (21.5)	340,219 (6.5)	3.9 (3.9–4.0)
Receipt of parenteral nutrition	6,620 (5.8)	29,316 (0.6)	11.0 (10.7–11.3)

NOTE. CI, confidence interval.

[a] All comparisons were significant at $P < .001$.

[b] Age dichotomized on age of 65 years; aged 65 years and older is the risk group.

and case-fatality rates. To our knowledge, this is the first study that used NIS weighted data. Only a few studies have used data on the US national level to examine the epidemiology of nosocomial BSI. One of these studies used a nonprobability sample of clinical data collected during 7 years (1995–2002) from 49 US hospitals.[50] Wisplinghoff and colleagues reported an incidence of 6 cases per 1,000 admissions. However, determinations of nosocomial BSI cases were based on reports by infection control practitioners, which has been shown by Stevenson et al[51] to produce a more conservative estimate than the use of *ICD-9-CM* codes, perhaps because of a combination of differences between these codes and the CDC/National Healthcare Safety Network criteria and/or a more refined application of the criteria by infection control practitioners. Conversely, the incidence in our study was congruent with that revealed in other reports based on smaller nonprobability samples.[17,41,52,53]

Our case-fatality rate of 21% is lower than those reported in the literature for nosocomial BSI, which varied between a low of 27% for ICU cases[4] in 1 large-scale study and a high of 57% for general cases and 67% for ICU cases in another study.[53] One explanation for our lower case-fatality rate is that we were unable to distinguish between ICU and non-ICU patients because this variable was not included in the data set. Many nosocomial BSI studies were conducted in critical care units in which severity of illness would increase the case-fatality rate. Another factor is that many studies did not specify the age group of the patients. Nosocomial BSI is the most common type of infection in neonatal ICUs.[54,55]

Results from this study on the incidence and case-fatality rates of nosocomial BSI should not be interpreted in isolation from the many factors that can affect the rate of nosocomial BSI in different institutions. Previous studies have reported that infection rates can be affected by the hospital size,[56,57] teaching affiliation,[57] and the admission unit.[7,53,58] Although case-mix analysis performed by using different surrogate markers is reported in the literature, a previous report suggested that case-mix indicators are overlapping in their importance and that the best set of markers is yet to be determined.[56] Therefore, the foremost aim of this national study

TABLE 3. Final Logistic Regression Model for Predicting Nosocomial Bloodstream Infection, Nationwide Inpatient Sample, 2003

Variable	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Cumulative maximum rescaled R^2
Central venous catheter use	11.90 (11.80–12.10)	4.76 (4.70–4.80)	0.10
Other infections	6.50 (6.40–6.50)	4.61 (4.55–4.70)	0.16
Receipt of mechanical ventilation	14.10 (13.90–14.30)	4.97 (4.90–5.00)	0.20
Trauma	2.70 (2.70–2.80)	1.98 (1.95–2.00)	0.21
Hemodialysis	5.20 (5.10–5.40)	4.83 (4.70–5.02)	0.21
Malnutrition	5.8 (5.70–5.90)	2.50 (2.43–2.54)	0.22

NOTE. CI, confidence interval; OR, odds ratio.

was to assess the incidence rate of nosocomial BSI across the country as these infections occur naturally in different settings and to establish priorities for infection control. Nevertheless, case-mix analysis by means of different surrogate markers is recommended in future studies.

Risk Factors

This study showed that 7 of the 10 leading causes of hospital admissions associated with nosocomial BSI were infection related. This is consistent with the findings in other studies that secondary nosocomial BSI rates are high, varying between 33%[21] and 84%.[58] The NIS data set recorded the underlying pathogen in only 37% of the nosocomial BSI cases, but of those reported, *S. aureus* was the most prevalent. This finding is similar to results from the study by Wisplinghoff et al,[4] in which they prospectively collected clinical data from 49 hospitals. Their findings revealed that *S. aureus* (20%), enterococci (9%), and *Candida* species (9%) were the most prevalent causes of nosocomial BSI. Similar what we found in the case in our study, Martin and colleagues[59] found that missing data were common (51%) in an existing data set. About two-thirds of nosocomial BSI patients were admitted because of injury or trauma, which were associated with a 4-fold increased risk for nosocomial BSI, similar to the findings of Pittet et al.[12] The consistency of these findings is expected because trauma injuries are associated with the loss of skin barriers, injury-associated immunosuppression, extensive use of invasive procedures, and massive blood transfusions. In the univariate analysis, an increased risk of nosocomial BSI was associated with mechanical ventilation, CVC use, hemodialysis, and malnutrition, which is consistent with the findings of other studies.[7,11,17,18,25,29-31,35,60]

In the multivariate analysis, 6 variables—CVC use, other infections, mechanical ventilation, trauma, hemodialysis, and malnutrition—showed moderate to large effects (ie, adjusted ORs) and also provided the most parsimonious model to explain the risk of nosocomial BSI. In this model and on the basis of the total maximum rescaled R^2, 21.7% of the variation in the occurrence of nosocomial BSI was explained by these 6 variables. The explanatory power of the model is low because many variables that would have been desired were not available in the NIS data set, including some individual-level factors (eg, use of immunosuppressant drugs, severity-of-illness rating) and system-level factors such as handwashing practices, nurse-to-patient ratios, length of stay prior to the diagnosis of the nosocomial BSI, type of unit (eg, ICU, respiratory, medical-surgical), and presence of antimicrobial resistance. For example, many studies have shown that severity of illness is an independent predictor of nosocomial BSI.[9,17,21] Although the data set does include a variable for length of stay, we did not include it in the final model because it was defined in the data set as "the period of time from admission to discharge." With this definition it was not possible to know the exact length of stay before the infection was diagnosed. The 6 variables in our final model are congruent with those in many studies that showed that all of these factors or most of them are independent predictors of nosocomial BSI.[17,18,61,62]

The key modifiable risk factors for nosocomial BSI identified in this study necessitate strict observance of aseptic technique and correction of preexisting or hospital-induced malnutrition as important strategies to prevent nosocomial BSI. Reports from the past 2 decades have consistently demonstrated that risk of infection declines following standardization of aseptic care.[39,63,64] Previous reports also have shown that low caloric intake is associated with increased risk of nosocomial BSI.[29] Moreover, hypoalbuminemia (ie, an indicator of protein deficiency linked to malnutrition) was significantly associated with increased risk of nosocomial BSI.[30,65]

Although the 60% increased risk associated with increased age was statistically significant, it was considerably lower than that associated with the other 6 factors of our final model and contributed very little to the prediction of nosocomial BSI. Another study showed that advanced age is a risk factor for nosocomial BSI,[12] as well as increased mortality due to nosocomial BSI.[14,66] Our findings showed, however, that other modifiable risk factors play the major role in the development of nosocomial BSI.

This study showed that men had a 70% greater risk of nosocomial BSI, which is consistent with the results of other

studies.[10-13,67] This study demonstrated that age and sex are not among the main influential risk factors for developing nosocomial BSI. In fact, the findings revealed that clinical risk factors had a large role in the process of acquisition of nosocomial BSI compared with that of nonmodifiable personal risk factors. In post hoc analyses, we observed a small (about 3%) increased prevalence of trauma and mechanical ventilation among men compared with women. This small difference does not seem to be able to explain the observed increased risk of nosocomial BSI in men in this study. Further study is needed to explain this sex-based difference.

Although this study has a number of strengths, including the fact it was based on a probability sample of US national data, several limitations exist. First, misclassifications may be associated with the use of *ICD-9-CM* codes for identifying nosocomial BSI cases. One possible explanation is that misclassification would be likely to be random, which biases the ORs toward unity. Given the moderate to large ORs revealed in this study, the conclusions would not be altered. Another possibility is that *ICD-9-CM* codes produce inflated estimates of the odds, as noted by Stevenson et al,[51] yet this would have no observable effect when the same amount of inflation contributes to both the numerator and the denominator. Nonetheless, further research is needed to determine the optimal use of *ICD-9-CM* codes to most closely approximate the criterion standard—CDC/National Healthcare Safety Network definitions and methods.

A second limitation of this study is the use of cross-sectional data. With the current data set structure, it was impossible to know whether the risk factors occurred before or after the outcome of interest (ie, nosocomial BSI). Some of this disadvantage could be offset if the data set were modified to include specific dates for secondary diagnoses and procedures (eg, dates of insertion and removal of CVCs). A third limitation, already noted, is the lack of data on other independent risk factors that, if routinely recorded in health records and included in the NIS, may help to explain a greater proportion of the variance in risk of nosocomial BSI.

Despite these limitations, results from this study can be used to measure the effectiveness of primary prevention measures that have been taken in the United States on a national scale to control nosocomial BSI. The use of *ICD-9-CM* codes in state and national NIS data sets represents an opportunity to perform broad surveillance (both benchmark, as in this study, and for trend analysis) of nosocomial BSI. This type of surveillance should be carried out routinely. At the same time, smaller scale and more refined surveillance studies conducted by infection control practitioners in healthcare settings provide invaluable data. Both types of studies provide important, yet different, data to inform infection control practice.

Strategies and guidelines for preventing nosocomial BSI have been established and reported adequately in the literature.[39,68-70] However, the effectiveness of applying many of these guidelines is not well evaluated. Finally, the numbers generated by this study can be used to alert healthcare policy makers in the United States to the negative consequences of nosocomial BSI on healthcare systems. Moreover, the results of our research may encourage healthcare policy makers to invest greater resources in infection control education, training, and surveillance programs.

CONCLUSIONS

From the results of this study we estimated that more than one-half million patients in the United States incurred a nosocomial BSI in 2003; 1 in 5 cases of nosocomial BSI were fatal. To date, this seems to be the first study that has used the NIS data set to generate national estimates of nosocomial BSIs. A number of modifiable risk factors were identified. Findings of this study were congruent with those of many smaller clinical prospective studies on nosocomial BSI, which provides validation of our results. This study demonstrated that it is possible to use *ICD-9-CM* codes to examine the effect of clinical factors on the risk of nosocomial BSI, although only a limited number of key variables for nosocomial infection surveillance are available at present. The NIS is an efficient and cost-effective data set for conducting surveillance of nosocomial BSI and, potentially, other nosocomial infections. The lack of exact dates and times associated with key variables such as the secondary diagnoses and medical and surgical procedures prevents determination of whether nosocomial BSIs can be causally attributed to the identified risk factor. Adding the date associated with the secondary diagnoses would, in essence, yield longitudinal rather than cross-sectional data and would add considerably to the robustness of the data set for nosocomial infection surveillance purposes. Nosocomial BSI is a major preventable cause of morbidity and mortality in the United States, and continued surveillance and intervention studies are warranted.

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APPENDIX

TABLE A. *International Classification of Diseases, 9th Revision, Clinical Modification* Diagnosis Codes Used to Identify Nosocomial Bloodstream Infections, United States Nationwide Inpatient Sample, 2003

Description	Code
Unspecified septicemia	038.9
Bacteremia	790.7
Septicemia during labor	659.3
Salmonella septicemia	003.1
Anthrax septicemia	022.3
Streptococcal septicemia	038.0
Other staphylococcal septicemia	038.1, 038.10, 038.19
Staphylococcus aureus septicemia	038.11
Pneumococcal septicemia	038.2
Septicemia due to anaerobes	038.3
Meningococcal septicemia	036.2
Septicemia due to *Haemophilus influenzae*	038.41
Septicemia due to *Escherichia coli*	038.42
Septicemia due to *Pseudomonas*	038.43
Septicemia due to *Serratia*	038.44
Gonococcemia	098.89
Septicemic plague	020.2
Septicemia due to unspecified GNB	038.49, 785.52, 038.40
Other specified septicemias	038.8
Septicemia due to *Listeria monocytogenes*	027.0
Disseminated systemic candidiasis	112.5
Viremia, unspecified, and herpetic septicemia	790.8, 054.5

NOTE. GNB, gram-negative bacteria.

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