ORIGINAL ARTICLE INFECTIOUS DISEASES

Inpatient costs, mortality and 30-day re-admission in patients with central-line-associated bloodstream infections

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Abstract

Previous work has suggested that central-line-associated bloodstream infection (CLABSI) is associated with increased costs and risk of mortality; however, no studies have looked at both total and variable costs, and information on outcomes outside of the intensive-care unit (ICU) is sparse. The aim of this study was to determine the excess in-hospital mortality and costs attributable to CLABSI in ICU and non-ICU patients. We conducted a retrospective cohort and cost-of-illness study from the hospital perspective of 398 patients at a tertiary-care academic medical centre from 1 January 2008 to 31 December 2010. All CLABSI patients and a simple random sample drawn from a list of all central lines inserted during the study period were included. Generalized linear models with log link and gamma distribution were used to model costs as a function of CLABSI and important covariates. Costs were adjusted to 2010 US dollars by use of the personal consumption expenditures for medical care index. We used multivariable logistic regression to identify independent predictors of in-hospital mortality. Among both ICU and non-ICU patients, adjusted variable costs for patients with CLABSI were *c.* $32 000 (2010 US dollars) higher on average than for patients without CLABSI. After we controlled for severity of illness and other healthcare-associated infections, CLABSI was associated with a 2.27-fold (95% CI 1.15–4.46) increased risk of mortality. Other healthcare-associated infections were also significantly associated with greater costs and mortality. Overall, CLABSI was associated with significantly higher adjusted in-hospital mortality and total and variable costs than those for patients without CLABSI.

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Introduction

Central lines constitute an important part of the treatment and management plan for patients who require long-term dialysis, nutritional support, or administration of medications such as antibiotics or chemotherapeutic agents. Although the additional vascular access allowed by these devices improves the ability to administer multiple therapies, there is also an increased risk of infection. Patients who require long-term venous access at baseline are sicker and require more care than patients without a central line, and the development of a bloodstream infection may result in substantial increases in cost and the risk of mortality [1].

There are *c.* 90 000 new central-line-associated bloodstream infections (CLABSIs) in the USA each year, accounting for between 600 million and 2.7 billion US dollars in annual direct costs [2]. Since 2008, the Center

for Medicare and Medicaid Services has no longer reimbursed the costs of additional care required to treat certain conditions ('never events') that develop in the hospital, including CLABSIs and other catheter-associated infections [3]. Reduced reimbursement places a significant financial burden on hospitals, particularly tertiary-care facilities, which tend to have higher rates of CLABSI, owing to the more severe case mix and consequent greater device use rates [4]. Given the increased financial burden, information regarding the potentially avoidable cost of CLABSI from the hospital perspective is critical for future evaluations of the cost-effectiveness of candidate interventions to reduce the incidence of CLABSI.

Economic evaluations of CLABSI have generated estimates that vary widely, depending on the definition of the infection, outcome variable, and study design [5–11]. Most published studies documenting the cost of CLABSI have not distinguished fixed from variable costs. However, as has been previously discussed, including fixed costs in estimates of the excess cost of healthcare-associated infection (HAI) may lead to an overly optimistic estimation of how much money can be saved as a result of infection control interventions [10,12]. In addition, few studies have evaluated economic or clinical outcomes, including mortality [1,7,13,14], outside of the intensive-care unit (ICU). Therefore, the objective of this study was to examine the relationship between CLABSI and total and variable inpatient costs, as well as in-hospital mortality and 30-day re-admission rates, in patients in ICU and non-ICU settings.

Methods

Study design and data sources

The purpose of this study was to estimate the burden of illness from the hospital perspective and other outcomes related to CLABSI. We conducted a retrospective cohort study of 398 patients hospitalized at the University of Rochester Medical Center, a tertiary-care, academic medical centre in Rochester, New York, between 1 January 2008 and 31 December 2010. Patients were eligible for the study if they had a new central line inserted during hospitalization, but were excluded if the new line was a replacement for an infected line that was present on admission. Clinical information was collected from electronic and paper medical records with a structured data collection tool by trained reviewers. Infection control data and administrative data on hospital costs, charges, International Classification of Diseases, Revision 9 (ICD-9) codes and diagnosis-related groups (DRGs) were obtained electronically.

Patient selection

We used radiological data to identify all patients who had central lines inserted during a hospitalization during the study period, as central lines required radiographic confirmation before being approved for use. Patients who developed CLABSI were identified through the National Healthcare Safety Network (NHSN) database used by the infection control program to track all CLABSIs in the facility. Patients met the definition of CLABSI if they had a line in place on the day before or on the day of a positive blood culture and either: (i) had a recognized pathogen cultured from one or more blood samples that could not be attributed to infection at another site; or (ii) had a commensal organism isolated from at least one blood sample and at least one sign or symptom (fever of >38°C, chills or hypotension) that was not attributable to an infection at another site [15]. All CLABSI cases were reviewed by trained infection preventionists and confirmed by the hospital epidemiologist, a board-certified infectious diseases physician.

From the list of all central lines inserted in the institution during the study period, we first identified patients who developed CLABSI during admission ('exposed'). All lines in which CLABSI did not develop were considered as potential control lines, except those contributed by patients who were already chosen as 'exposed'. From this list of eligible 'unexposed' lines, a simple random sample was chosen with a random number generator. All CLABSI patients and the selected 'unexposed' patients were included in the cohort, and were followed forward to determine outcomes. Patients may have had multiple qualifying lines inserted during the study period. For CLABSI cases, we chose the line that was associated with the infection. For control lines, we randomly selected from all eligible lines. Once a line was selected, all remaining lines for that patient were removed from the eligible pool.

Outcome assessment

The primary outcome of this study was inpatient costs. Direct inpatient costs can be divided into fixed costs and variable costs. Fixed costs are those that cannot be avoided in the short term, and include things such as facility maintenance, equipment, and labour. In contrast, variable costs, such as those for drugs and consumables, can be avoided and are therefore more relevant to policy-makers in the realm of hospital-acquired infections [12]. We modelled both total (fixed and variable) costs and variable costs alone, which were generated by hospital accountants using micro-costing methods for all services and goods consumed during hospitalization [16]. Costs for patients who were hospitalized in 2008 or 2009 were adjusted to 2010 US dollars with the personal consump-

tion expenditures index, a price index constructed by the US Bureau of Economic Analysis that improves upon the commonly used medical component of the consumer price index by including third-party payers and allowing for substitution within the bundle of goods and services on which the index is calculated [17].

The secondary outcomes in this study were all-cause in-hospital mortality and 30-day re-admission rate. CLABSI-specific mortality and re-admission were not collected, because of the subjectivity in determining cause of death and because of the unavailability of information on reason for re-admission. In-hospital mortality was defined dichotomously as death from any cause during hospitalization. Re-admission was defined dichotomously as re-admission to the University of Rochester Medical Center for any reason within 30 days of discharge after the index hospitalization. Information on admissions to other hospitals was not available, but the frequency is likely to be low.

Covariates

Factors shown to independently predict cost in previous economic evaluations of CLABSI were collected. In order to account for patients who require more care, we collected information to compute the Acute Physiologic and Chronic Health Evaluation (APACHE) II score [18] at the time of line insertion (±3 days) and the Deyo–Charlson Comorbidity Index [19]. APACHE II was originally developed for use in the ICU, but has been shown to predict mortality in both ICU and non-ICU patients with bacteraemia [20]. We collected information on DRGs, which is a method of classifying patients according to severity and resource utilization during hospitalization [21]. Because the DRG system used to classify patients varies by payer, the DRG system was recorded. The development of other HAIs during hospitalization was identified on the basis of clinical diagnosis recorded in the medical chart. Major surgical procedures were identified from ICD-9 codes, and classified by use of the Healthcare Utilization Project procedure classification tool [22].

The presence of multiple catheters was defined as multiple catheters in place at any time during the study period, regardless of duration. For each patient, the number of days spent in an ICU and the number of days spent in an intermediate-care ('step-down') unit were tabulated. The overall length of stay was computed as the time from admission to discharge for all patients, and is the sum of days spent in the ICU, step-down units, and on general medical floors. Any ICU stay was defined as a dichotomous variable; patients with one or more days spent in the ICU were considered to be ICU patients. Missing ICD-9 codes or lack of documentation in the chart was presumed to indicate the lack of the procedure or condition of interest. There were no other missing values. This study was reviewed and approved by the University of Rochester's Research Subjects Review Board.

Data analysis

Multivariable cost models were implemented in Stata 12 (Stata, College Station, TX, USA). All other analyses were conducted with SAS V9.3 (SAS, Cary, NC, USA). The clinical characteristics and outcomes of patients with and without CLABSI were compared across groups by the use of chi-square tests for categorical variables and Wilcoxon rank sum tests for continuous variables.

Total costs and variable costs (2010 US dollars) were modelled with multivariable generalized linear models with a log link, which allows modelling of skewed data without the bias associated with retransformation or the difficulty of interpreting estimates on the log scale [23]. Modified Park post-tests were used to confirm that, in both models, the gamma distribution was the most suitable choice [24]. All non-outcome variables (shown in Table 1) were included in cost models, and retained regardless of statistical significance, except for overall length of stay and death, which were considered to be intermediary variables. Average marginal (for continuous variables) or incremental (for categorical variables) effects were computed with the 'margins' command in Stata. Separate cost models were constructed for ICU patients and non-ICU patients.

Multivariable logistic regression was used to model the risk of in-hospital mortality and 30-day re-admission as a function of CLABSI and other covariates. Covariates were identified for the model on the basis of an association with CLABSI in the bivariate analysis at $p < 0.20$, and were retained in the model regardless of statistical significance. Variance inflation factors were evaluated to detect problems with predictor collinearity [25].

Results

On average, CLABSI patients were more likely to have had other HAIs (67.5% vs. 30.4%, p 0.01) during hospitalization than non-CLABSI patients (Table 1). CLABSI patients had a greater severity of underlying illness as measured by the APACHE II score at the time of line insertion, but there was no difference in the Deyo–Charlson Comorbidity Index. Patients also spent more time in the ICU and step-down units, but there was no difference in patient race. The unadjusted difference in variable hospital costs between patients with CLABSI and those without CLABSI was

TABLE 1. Characteristics of the study population (*n* = 398)

Characteristic	CLABSI	No CLABSI	p
No. of patients	197	201	
Age (years), median (IQR)	58.0 (26.0)	59.0 (26.0)	0.30
Males, *n* (%)	131 (66.5)	116 (57.7)	0.07
Race, *n* (%)			
White	138 (70.1)	155 (77.1)	0.26
Black	38 (19.3)	31 (15.4)	
Other	21 (10.7)	15 (7.5)	
Other HAI, *n* (%)	133 (67.5)	61 (30.4)	0.01
Dialysis, *n* (%)	48 (24.4)	28 (13.9)	0.01
Major surgery, *n* (%)	113 (57.4)	85 (42.3)	<0.01
Multiple catheters, n (%)	66 (33.5)	17 (8.5)	<0.0001
Overall length of stay (days), median (IQR)	43.0 (54.0)	13.0 (18.0)	<0.0001
1–7	1 (0.50)	49 (24.4)	
>7	196 (99.5)	152 (75.6)	
Days in step-down care, *n* (%)			
None	121 (61.4)	174 (86.6)	<0.0001
1–7	28 (14.2)	18 (9.0)	
>7	48 (24.4)	9 (4.5)	
Days in the ICU, *n* (%)			
None	101 (51.3)	147 (73.1)	<0.0001
1–7	33 (16.8)	32 (15.9)	
>7	63 (32.0)	22 (11.0)	
APACHE II score, median (IQR)	14.0 (7.0)	11.0 (7.0)	<0.0001
CCI, median (IQR)	2.0 (3.0)	2.0 (2.0)	0.23
DRG weight, median (IQR)			
CMS-DRG (*n* = 179)	5.16 (8.59)	1.79 (2.75)	<0.0001
AP-DRG (*n* = 177)	12.1 (23.4)	4.36 (7.88)	<0.0001
APR-DRG (*n* = 42)	9.34 (21.3)	3.45 (4.68)	<0.01
Outcomes			
Total costs, USD 2010, median (IQR)	118 823 (172 555)	25 976 (44 270)	<0.0001
Variable costs, USD 2010, median (IQR)	72 563 (112 288)	15 846 (28 285)	<0.0001
30-day re-admission, *n* (%)	47 (33.3)	52 (28.4)	0.34
n at risk of re-admission	141	183	
In-hospital mortality, *n* (%)	56 (28.4)	18 (9.0)	<0.0001

APACHE II, Acute Physiologic and Chronic Health Evaluation version II; CCI, Carlson Comorbidity Index; CLABSI, central-line-associated bloodstream infection; DRG, diagnosis-related group; HAI, healthcare-associated infection; ICU, intensive-care unit; IQR, interquartile range; USD, United States dollars.

TABLE 2. Characteristics of patients with central-line-associated bloodstream infection (CLABSI) (*n* = 197)

Characteristic	*n*	%
CLABSI pathogen		
Coagulase-negative *Staphylococcus*	64	32.5
Candida species	33	16.8
Klebsiella species	26	13.2
Escherichia coli	11	5.6
Enterococcus faecium	13	6.6
Other *Enterococcus*	36	18.3
Methicillin-resistant *Staphylococcus aureus*	13	6.6
Any CLABSI complications[a] during hospitalization	20	10.2
Recurrent bacteraemia	11	5.6
Other	9	4.6

	Median	IQR
Pre-CLABSI LOS (days)	24.0	30.0
Post-CLABSI LOS (days)	18.0	27.0
Total LOS (days)	43.0	54.0

CLABSI, central-line-associated bloodstream infection; IQR, interquartile range; LOS, length of stay.
[a]Defined as infection with same pathogen between 72 h before and 30 days after CLABSI diagnosis. Other complications included endocarditis, osteomyelitis, septic arthritis, meningitis, and septic thrombophlebitis.

c. $56 800. CLABSI patients were at higher risk of dying in the hospital, but 30-day re-admission rates were similar between the two groups.

Table 2 shows the characteristics of CLABSI patients in the cohort. The median (interquartile range) pre-CLABSI length of stay and post-CLABSI length of stay were 24.0 days (30.0 days) and 18.0 days (27.0 days), respectively. The most commonly isolated pathogens were coagulase-negative *Staphylococcus* (32.5%) and *Candida* species (16.8%). CLABSI complications, such as bacteraemia, occurred in *c.* 10% of patients.

Table 3 shows results from the multivariable cost models for non-ICU patients. Because the models used a log link function, the coefficients can be interpreted as the percentage change in costs for each one-unit increase in the independent variable. After the effects of severity, presence of another HAI and other covariates had been accounted for, non-ICU patients with CLABSI had a 76% greater total cost than non-ICU patients without CLABSI, which translates to *c.* $50 000. Similarly, the presence of CLABSI was associated with 80% greater variable costs than for patients without CLABSI, corresponding to *c.* $33 000 in excess variable cost in our sample. The presence of another HAI was significantly associated with a 75% increase in variable costs. As shown in Table 4, the absolute excess costs were nearly identical among ICU patients. CLABSI was associated with *c.* $49 600 in excess total costs and $32 400 in excess variable costs. However, this resulted in smaller incremental effects, because total costs were much higher for ICU patients than for non-ICU patients. Each day spent in the ICU was associated with *c.* $1700 in additional variable costs.

Between 1 January 2008 and 31 December 2010, 74 patients died during hospitalization, resulting in a mortality rate of 18.6%. The results of the multivariable logistic regression model for in-hospital mortality are shown in Table 5. In bivariate analysis, CLABSI patients were at a four-fold increased risk of dying. On multivariable analysis, only CLABSI, other HAI and APACHE II score were independent predictors of death. After other HAI, APACHE II and the presence of multiple catheters had been controlled for, CLABSI patients had a 2.27-fold (95% CI 1.15–4.46) greater risk of mortality than non-CLABSI patients. There was no difference in the 30-day re-admission rate on bivariate or multivariable (data not shown) analyses.

Discussion

There has been substantial research on the design and evaluation of interventions to reduce the risk of CLABSI, and progress has been observed. The most recent NHSN report shows a 58% decrease in ICU CLABSI rates from 2001 to 2008 [26]. Despite recent successes in the reduction of

TABLE 3. Estimated adjusted excess total and variable inpatient hospital costs (2010 US dollars (USD)) for patients with no intensive-care unit stay (n = 248)

	Adjusted[a] total costs (2010 USD)			Adjusted[a] variable costs (2010 USD)		
Characteristic	**Coefficient**	**Excess cost**	**p**	**Coefficient**	**Excess cost**	**p**
CLABSI	0.762	50 094	<0.0001	0.797	32 984	<0.0001
Other HAI	0.755	53 068	<0.0001	0.752	33 447	<0.0001
Major surgery	0.18	12 755	0.05	0.203	9524	0.03
APACHE II, per point	0.029	2121	<0.01	0.030	1384	<0.01
Age, per year	−0.009	−639	0.01	−0.008	−383	0.01

APACHE, Acute Physiologic and Chronic Health Evaluation; CLABSI, central-line-associated bloodstream infection; HAI, healthcare-associated infection.
[a]All costs were modelled by generalized linear regression with log link and gamma distribution. In addition to the variables listed in the table, estimates were also adjusted for gender, race, Charlson Comorbidity Index, number of days in a step-down unit, presence of multiple catheters, diagnosis-related group (DRG) weight, and DRG system (AP-DRG, CMS-DRG, or APR-DRG).

TABLE 4. Estimated adjusted excess total and variable inpatient hospital costs (2010 US dollars (USD)) for patients with any intensive-care unit (ICU) stay (n = 150)

	Adjusted[a] total costs (2010 USD)			Adjusted[a] variable costs (2010 USD)		
Characteristic	**Coefficient**	**Excess cost**	**p**	**Coefficient**	**Excess cost**	**p**
CLABSI	0.198	49 618	0.04	0.211	32 412	0.03
Other HAI	0.561	122 217	<0.0001	0.595	78 832	<0.0001
Multiple catheters	0.362	96 000	<0.01	0.386	63 096	<0.01
ICU stay, per day	0.011	2921	<0.0001	0.011	1726	<0.0001
Step-down stay, per day	0.008	2111	<0.0001	0.008	1280	<0.0001

CLABSI, central-line-associated bloodstream infection; HAI, healthcare-associated infection.
[a]All costs were modelled by generalized linear regression with log link and gamma distribution. In addition to the variables listed in the table, estimates were also adjusted for gender, age, race, major surgical procedure, Acute Physiologic and Chronic Health Evaluation (APACHE) II score, Charlson Comorbidity Index, diagnosis-related group (DRG) weight, and DRG system (AP-DRG, CMS-DRG, or APR-DRG).

TABLE 5. Multivariable logistic regression of in-hospital mortality (n = 398)

Characteristic	**Crude OR (95% CI)**	**Adjusted[a] OR (95% CI)**
CLABSI	4.04 (2.27–7.17)	2.27 (1.15–4.46)
Other HAI	4.19 (2.36–7.45)	2.62 (1.30–5.30)
Multiple catheters	4.77 (2.76–8.26)	1.92 (0.97–3.80)
APACHE II score, per 5 points	2.02 (1.63–2.51)	1.71 (1.33–2.20)
Step-down stay, per 7 days	1.15 (1.05–1.25)	1.09 (0.99–1.20)
ICU stay, per 7 days	1.08 (1.01–1.15)	1.08 (0.98–1.18)
Dialysis	2.97 (1.67–5.22)	1.05 (0.51–2.18)
OLOS, per 7 days	1.05 (1.02–1.07)	0.97 (0.92–1.02)
Major surgery	1.24 (0.75–2.05)	0.72 (0.38–1.37)
Male sex	0.85 (0.52–1.46)	0.71 (0.39–1.29)

APACHE II, Acute Physiologic and Chronic Health Evaluation Version II; CLABSI, central-line-associated bloodstream infection; HAI, healthcare-associated infection; ICU, intensive-care unit; OLOS, overall length of stay.
[a]Adjusted for the presence of multiple catheters, which was classified as a confounder based on a 10% change in the parameter estimate for CLABSI when removed from the model.

CLABSI rates in the ICUs of those facilities contributing data to the NHSN, significant work remains to reduce the impact of these infections on our healthcare system. In an effort to incentivize quality improvement, Medicare no longer reimburses for CLABSIs and other HAIs. However, studies suggest that not all HAIs are preventable [27,28], and hospitals must absorb the costs of CLABSIs for patients with Medicare coverage. Therefore, estimates of the excess cost and mortality potentially attributable to CLABSIs are critical to estimate the financial impact of reduced reimbursement and to evaluate the potential cost savings of new interventions.

We observed that CLABSI was associated with significantly higher total and variable costs than those for patients without CLABSI. On average, CLABSI was associated with *c.* $33 000 in excess variable costs, regardless of whether patients were in the ICU or not. This figure is similar to some previously published estimates. Pittet *et al.* [6] examined excess costs of nosocomial bloodstream infections in a matched case–control study of surgical ICU patients, and observed *c.* $41 000 (1994 US dollars) in excess total costs. In another analysis of nosocomial bloodstream infections in the ICU setting, Digiovine *et al.* [8] observed that survivors with infections had more than $34 000 (1995 US dollars) in excess costs relative to patients without bloodstream infections. However, both estimates arise from matched studies composed of ICU patients who did not die during hospitalization. Both studies analysed total direct costs rather than variable costs, and were also conducted almost 20 years ago, limiting comparability with our results.

Most of the previous research on the economics and outcomes of CLABSI has been conducted exclusively among ICU patients. Our study was conducted among both ICU and non-ICU (general medical and step-down) patients of a large, tertiary-care, academic hospital. We observed that, among ICU patients, each additional day of ICU stay was associated with *c.* $1700 in excess variable costs. Each day in the step-down unit stay added *c.* $1280 in variable costs for ICU patients, but there was no increase in cost per step-down day

among non-ICU patients. Development of another HAI was associated with the largest incremental increase in variable costs: approximately $34 000 and $79 000 for non-ICU and ICU patients, respectively. As expected, APACHE II score was strongly associated with cost, with each additional point equating to *c.* $1300 in extra variable costs, but only among non-ICU patients.

In our study, patients with CLABSI were more than twice as likely to die as patients without CLABSI, even after APACHE II score and the presence of other HAIs had been controlled for. An association between CLABSI and crude in-hospital mortality has been observed in several studies [1,7,13,14,29], but, in some cases, CLABSI has not remained an independent predictor of mortality in multivariable analysis [7,29]. This may be attributable to a small number of CLABSI cases, resulting in reduced power to detect true associations. In the study by Dimick *et al.* [29], for example, the mortality among the nine CLABSI patients was 56%, as compared with 21% among 251 non-CLABSI patients (p 0.02). After the effects of APACHE III score had been controlled for, CLABSI was no longer an independent predictor (adjusted OR 4.3, 95% CI 0.9–19.9). There was no difference in the 30-day re-admission rates between patients with and without CLABSI (33.3% vs. 28.4%, respectively, p 0.34), even after removal of those not at risk of re-admission (i.e. those who died).

The primary limitation of this study is the inability to account for the timing of infection in our cost models. Recently, the importance of the time-dependent nature of infection has been highlighted in several papers and editorials [10,12,30,31]. However, our data did not allow us to differentiate between costs that occurred before and after the CLABSI event. Although this most likely results in an overestimation of potential cost savings in the context of an intervention, information about the total and variable costs for patients who develop CLABSI is still useful for hospital administrators. In addition, this is a limitation that few studies examining the relationship between HAI and inpatient costs have been able to overcome.

Residual confounding is always a concern in observational research, and there is a possibility that the observed differences in cost are attributable to some unmeasured factor, rather than a true difference in costs and mortality resulting from CLABSI infection. Sample restriction, matching and adjustment are common methods to control for measured confounders, but none of these methods addresses confounders that are unobserved. Because of the small sample size, we chose to use multivariable adjustment to avoid excluding any patients. Randomization and instrumental variable analysis are both superior methods for addressing confounding resuting from measured and unmeasured variables, but were not feasible in this study.

This study is also limited by a potential lack of generalizability. We used data from an academic medical centre, which may be more likely to use newer and more expensive treatments as part of routine care. Therefore, our results may not be applicable to smaller community hospitals or to Federal institutions. In addition, there may be significant variability in micro-costing methods across institutions, resulting in substantially different estimates of cost. However, the use of the relative measure (e.g. an 80% increase in variable costs for CLABSI patients in the non-ICU setting) rather than the absolute dollar estimate should prove more applicable across a range of study settings. We lacked re-admission data for other institutions; however, the rate of switching between healthcare facilities is small and unlikely to differ between CLABSI and non-CLABSI patients. Finally, we used the NHSN definition of CLABSI, which is a surveillance definition and is not as restrictive as the clinical definition of CRBSI. This may have resulted in some patients with bloodstream infections unrelated to their central lines being classified as 'exposed'. However, our definition is consistent with the case definition commonly employed by hospitals for surveillance purposes.

This study also has several strengths. To the best of our knowledge, it is the first study of CLABSI to analyse total and variable costs separately. In addition, this is one of the few studies that has not focused exclusively on ICU residents, allowing for wider generalization than previous estimates of excess cost. We used a robust multivariable modelling methodology to model costs as a function of the presence and severity of underlying illness, DRG, and other factors that influence hospital costs. We also were able to incorporate both administrative and clinical data, manually collecting the information necessary to compute the APACHE II score, which is not traditionally available in electronic health data.

In summary, we observed that CLABSI was associated with significantly higher hospital costs and risk of in-hospital mortality. These costs represent a substantial burden to hospitals, particularly for patients covered by Medicare. Continued reductions in CLABSI rates should help to offset some, but not all, costs for these patients. Future work should examine costs while accounting for timing of infection in both ICU and non-ICU patients.

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Transparency Declaration

The Authors declare no conflicts of interest.

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