Prevalence and risk factors for bloodstream infection present on hospital admission

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Abstract

Background: Bloodstream infection present on hospital admission (BSI-POA) is a major cause of morbidity and mortality. The purpose of this study was to measure prevalence and describe the risk factors of patients with BSI-POA and to determine the prevalence of resistance in isolates by admission source.

Methods: We conducted a retrospective cohort study of patients discharged from three hospitals in New York City between 2006 and 2014. BSI-POA was defined as BSI diagnosed within 48 h of hospitalisation.

Results: The prevalence for BSI-POA was 5307/315,010 discharges (1.7%). The odds of being admitted with BSI-POA were greatest among patients admitted with renal failure, chronic dermatitis, malignancies and prior hospitalisation. Odds ratios and 95% confidence intervals (CI) were 2.72 (95% CI = 2.56–2.88), 2.15 (95% CI = 1.97–2.34), 1.76 (95% CI = 1.64–1.88) and 1.59 (95% CI = 1.50–1.69), respectively. The largest proportion of BSI-POA presented with *Staphylococcus aureus* (48.4%), followed by *Enterococcus faecalis/faecium* (20.3%), *Klebsiella pneumoniae* (16.2%), *Streptococcus pneumoniae* (8.7%), *Pseudomonas aeruginosa* (4.2%) and *Acinetobacter baumannii* (2.2%). Overall, 44% of those admitted from nursing homes presented with antibiotic resistant strains versus 34% from other hospitals and 31% from private homes ($P = 0.002$).

Conclusion: Understanding the risk factors of patients who present to the hospital with BSI could enable timely interventions and better patient outcomes.

Keywords

Bloodstream infection, community-acquired bloodstream infection, present on admission

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Introduction

Bloodstream infection present on hospital admission (BSI-POA) is a life-threatening condition that results in high costs and resource utilisation (Sogaard et al., 2011). In a previous study conducted at the same site as the current study, the incidence of BSI-POA was reported as 18.6 per 1000 discharges (Cohen et al., 2013), while overall population-based incidence of BSI-POA in Canada, Europe and the United States is in the range of 81.6–189 per 100,000 person years (Laupland, 2013; Sogaard et al., 2011; Uslan et al., 2007). In-hospital case fatality rates associated with BSI-POA have been estimated between 15% and 55% (Kontula et al., 2016; Sogaard et al., 2011). Concerns about the increasing frequency of BSI-POA have been noted, especially due to multiple-resistant organisms (Orsini et al., 2012).

Although a number of population-based studies have investigated BSI (Artero et al., 2010; Kontula et al., 2016; Uslan et al., 2007), few have distinguished between community- and healthcare-associated infections and such data are necessary for targeting treatment and prevention efforts. Even less is known about the prevalence of BSI-POA by admission source (e.g. other hospital, nursing home [NH],

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private home), an important factor that can inform interventions. Further, many studies on BSI-POA have been limited to specific organisms (Courjon et al., 2015; Wang et al., 2015), single institutions (Akoua-Koffi et al., 2015; Artero et al., 2010), elderly (Huang et al., 2012) or intensive care units (Artero et al., 2010).

Understanding the characteristics that put patients at risk for BSI-POA and knowing the causative organisms for those BSIs could provide vital information to detect and treat emerging pathogens and potentially reduce resistance and mortality rates (Kontula et al., 2016). Therefore, the purpose of this study was to measure prevalence and describe the risk factors of patients with BSI-POA and to determine the prevalence of resistance in isolates by admission source.

Methods

Design, sample and setting

We conducted a retrospective cohort study using data from a larger study funded by the National Institutes of Health (Health Information Technology to Reduce Healthcare-Associated Infections, R01NR010822) previously summarised in Apte et al. (2011), including all adult patients (age ≥ 18 years) discharged between 1 January 2006 and 31 December 2014 from three hospitals which are part of a large academic health system in New York City. The three facilities include a 220-bed community hospital and two tertiary/quaternary care hospitals with 650 and 850 beds, which serve a diverse group of patients. The institutional review boards of Columbia University Medical Center and Weill Cornell Medical Center approved the study.

Data collection

Data were extracted from a clinical data warehouse containing various electronic sources shared by the hospitals including laboratory reports and administrative records which provided age, gender, prior hospitalisation, admission source and International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis codes. Health status at the time of admission was determined based on ICD-9-CM diagnosis codes with symptoms present on admission and included the following diagnoses: diabetes mellitus, burns, chronic dermatitis, malignancies, renal failure and weighted Charlson Comorbidity Index (CCI) scores (Charlson et al., 1987).

Measures

A team of clinicians and researchers used electronically available data to develop and validate electronic algorithms to identify BSI based on the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network

(NHSN) definitions (Centers for Disease Control and Prevention, 2016). Patients who presented with a BSI within 48 h of admission were considered to have BSI-POA. Patients discharged from the hospital and then readmitted within 30 days with a BSI were excluded (Horan et al., 2008). The algorithms utilised microbiology results and ICD-9-CM billing codes to identify infections and antimicrobial susceptibility patterns for the following six organisms: *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Enterococcus faecalis/faecium*, *Streptococcus pneumoniae*, *Klebsiella pneumoniae* and *Acinetobacter baumannii*, selected because they were among the most prevalent organisms causing BSI and also commonly develop resistance to one or more antimicrobials (World Health Organization, 2015). Antimicrobial resistance for the six organisms studied was defined as follows: *S. aureus* = oxacillin; *P. aeruginosa* = levofloxacin; *E. faecalis/faecium* = vancomycin; *S. pneumoniae* = penicillin G and penicillin V; *K. pneumoniae* = imipenem/meropenem; and *A. baumannii* = ampicillin-sulbactam. Development and validation of definitions are summarised in Apte (Apte et al., 2011).

Statistical analysis

Descriptive statistics were computed for all variables including percentages, frequencies, means and standard deviations (SD). Bivariate analyses were performed to determine the association between BSI-POA and potential predictor variables (admission source, prior hospitalisation, age, sex, renal failure, diabetes mellitus, malignancy, chronic dermatitis and burns). Chi-square tests were used for categorical variables and Wilcoxon rank-sum test for the CCI. Those variables significantly associated with BSI-POA in the bivariate analyses ($P < 0.05$) were then included in a multiple logistic regression model. Burns were not included in the multivariable analysis due to small sample size ($n = 4$). CCI was also removed from the multivariable analysis because the composite CCI score included some of the predictors that were analysed in our model. Using Chi-square or Wilcoxon rank sum, we compared excluded patients with the rest of the sample and found no statistically significant ($P < 0.05$) differences with regard to age and sex.

Next, for each of the six organisms studied, the proportion of antibiotic-resistant isolates was computed. Bivariate analyses were performed to compare the proportion of antibiotic-resistant strains by admission source separately for each organism using Chi-square or Fisher's exact test. Data analyses were conducted using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA).

Results

Of the 713,739 discharges during the data collection period, admission source was available from 315,010 (44%). NHs,

Table 1. Description of study population and incidence of BSI-POA.

	BSI-POA (n = 5307) (n (%))	Non-BSI-POA (n = 309,703) (n (%))	P value
Admission source			< 0.001
Nursing home	735 (13.8)	15,036 (4.9)	
Private home	4014 (75.6)	254,290 (82.1)	
Hospital transfer	558 (10.5)	40,377 (13)	
Age category (years)			< 0.001
18–64	2433 (45.8)	181,488 (58.6)	
65–84	2035 (38.3)	99,371 (32.1)	
≥ 85	839 (15.8)	28,844 (9.3)	
Gender			< 0.001
Female	2478 (46.7)	171,843 (55.5)	
Male	2829 (53.3)	137,860 (44.5)	
Co-morbid conditions			
Diabetes mellitus	1512 (28.5)	67,208 (21.7)	< 0.001
Malignancies	1128 (21.3)	41,072 (13.3)	< 0.001
Renal failure	2140 (40.3)	50,008 (16.1)	< 0.001
Burns	4 (0.1)	2342 (0.8)	< 0.001
Chronic dermatitis	674 (12.7)	15,271 (4.9)	< 0.001
Prior hospitalisation	3405 (64.2)	139,979 (45.2)	< 0.001
CCI score: mean [SD]	2.9 [2.6]	1.8 [2.3]	< 0.001

private homes and other hospitals accounted for 2%, 36% and 6%, respectively. Among the 315,010 discharges were 5307 cases of BSI-POA resulting in a prevalence rate of 1.7%. Male patients were more likely to be admitted with a BSI compared with female patients (53.3% vs. 46.7%). Admission source, age, gender, diabetes mellitus, malignancies, renal failure, burns, chronic dermatitis and prior hospitalisation were significantly associated with BSI-POA in bivariate analyses. Patients with BSI-POA had a significantly higher mean CCI score (mean = 2.9 ± SD = 2.6, compared with those patients without BSI-POA mean = 1.8 ± SD = 2.3), $P < 0.001$ (Table 1).

In the multivariable analysis shown in Table 2, significant predictors of BSI-POA included renal failure, chronic dermatitis, malignancies, prior hospitalisation, older age, male gender and admission from NHs. We found no association between diabetes mellitus and admission with BSI (odds ratio [OR] = 0.97, 95% confidence interval [CI] (0.91–1.03).

Table 3 summarises the rates of isolates causing BSI-POA with these six organisms, comparing patients by admission source. Among patients admitted with BSI with one of the six organisms studied (n = 1509), the largest proportion presented with *S. aureus* (n = 731, 48.4%), followed by *E. faecalis/faecium* (n = 306, 20.3%), *K. pneumoniae* (n = 244, 16.2%), *S. pneumoniae* (n = 131, 8.7%),

Table 2. Associations between patient characteristics and BSI-POA in multivariable logistic regression analysis.

Predictors	OR (95% CI)
Renal failure	2.72 (2.56–2.88)
Chronic dermatitis	2.15 (1.97–2.34)
Malignancies	1.76 (1.64–1.88)
Prior hospitalisation	1.59 (1.50–1.69)
Age (reference = 18–64 years)	
≥ 85	1.37 (1.26–1.49)
65–84	1.12 (1.05–1.19)
Male (reference = female)	1.25 (1.19–1.33)
Diabetes mellitus	0.97 (0.91–1.03)
Admission source (reference = nursing home)	
Private home	0.45 (0.41–0.49)
Hospital transfer	0.42 (0.38–0.48)

P. aeruginosa (n = 65, 4.2%) and *A. baumannii* (n = 33, 2.2%). One-third of the BSI-POA cases with these organisms were antibiotic-resistant. The percent of resistant

Table 3. Isolates causing BSI-POA by admission source.

Isolate	Total	Hospital transfer	Private home	Nursing home	P value
		Resistant (n (%))	Resistant (n (%))	Resistant (n (%))	
<i>S. aureus</i>	731	43 (41)	200 (38)	60 (58)	0.002*
<i>P. aeruginosa</i>	64	4 (44)	14 (27)	1 (25)	0.07†
<i>S. pneumoniae</i>	131	0 (0)	25 (20)	1 (17)	0.26†
<i>K. pneumoniae</i>	244	7 (28)	52 (27)	10 (36)	0.65*
<i>E. faecalis/faecium</i>	306	13 (25)	47 (23)	12 (26)	0.85*
<i>A. baumannii</i>	33	1 (14)	3 (14)	1 (20)	0.26†
Total	1509	68 (34)	341 (31)	85 (44)	0.002*

*Chi-square.

†Fisher's exact test.

organisms was significantly greater in NH than other sources ($P = 0.002$), but when broken down by organisms, only *S. aureus* showed a significantly higher proportion of resistant strains in patients admitted from NHs.

Discussion

To our knowledge, this is the first study to assess the prevalence, potential risk factors and predictors associated with BSI-POA and the prevalence of resistance in isolates by admission source using a large sample size and data collected over a nine-year time period. Even when accounting for age, patients who were admitted from NHs were significantly more likely to have a BSI-POA than patients who were admitted from private homes or other hospitals. Consistent with our findings, other investigators examined BSI among NH and non-NH residents and established that NH exposure was a risk factor for BSI-POA caused by gram-positive and gram-negative organisms (Huang et al., 2012) and another study reported that residence in a long-term care facility was associated with gram-negative BSI-POA (Pop-Vicas et al., 2009). Limitations of these studies included the fact that patients were from a single hospital. In the current study, we included several hospitals.

Similar to our results, others have found older age and male gender to be significant predictors of BSI-POA (Akoua-Koffi et al., 2015; Uslan et al., 2007). Among the patient characteristics studied, patients with renal failure, chronic dermatitis, malignancies and prior hospitalisation had the highest odds of being admitted with a BSI. These findings are consistent with at least two previous studies that reported renal failure and malignancies to be associated with BSI-POA (Cheong et al., 2008; Rodriguez-Bano et al., 2010). Patients with these conditions generally present with multiple co-morbidities, including changes in immune function which influence their risk of BSI

acquisition (James et al., 2008; Stewart et al., 2009) and dermatitis which compromises the skin barrier. One study reported that diabetes mellitus increased the odds of BSI-POA in severely ill patients (OR = 1.42, 95% CI = 1.10–1.82) (McKane et al., 2014), but we found no such association. The fact that diabetes mellitus was not associated with BSI-POA warrants additional research.

Among the organisms studied, *S. aureus* accounted for almost half of the isolates associated with BSI-POA and a higher proportion of resistant strains among those admitted from NHs compared with those admitted from private homes and other hospitals. Reports of resistance in *S. aureus*, primarily methicillin-resistant *S. aureus* (MRSA) are common in this setting. In northern Italy, long-term care residents were more likely to be colonized with MRSA ($P < 0.0001$) than geriatric patients in an acute-care hospital (March et al., 2010).

Consistent with other studies, there was also a higher proportion of resistant strains of *K. pneumoniae* causing BSI-POA among patients admitted from NHs, although not significant. Pop-Vicas et al. (2009) reported a 16-fold increase in BSI caused by gram-negative bacteria including *K. pneumoniae* among the elderly, particularly those residing in long-term care (Pop-Vicas et al., 2009).

Most cases of *P. aeruginosa* BSI-POA were admitted from private homes. Cases of community-acquired *P. aeruginosa* have been noted among vulnerable individuals such as those with cystic fibrosis, and rarely, cases have been noted among healthy individuals (Huhulescu et al., 2011; Kunimasa et al., 2012). Resistant strains, however, were highest among patients transferred from another hospital; this is not surprising considering that patients who have had previous prolonged contact with healthcare environments are exposed to more multidrug resistant pathogens and are more likely to have received antibiotics (Huang et al., 2010; Karkada et al., 2011). Twenty percent

of the *S. pneumoniae* resistant strains were isolated from patients admitted from private homes, perhaps related to prior antibiotic exposure (Lynch and Zhanel, 2009). We found a similar resistance pattern for *E. faecalis/faecium* among all admission sources. Likewise, a team of researchers reported that *E. faecalis/faecium* has emerged as a cause of multidrug resistance and poses a challenge across health-care settings (Arias et al., 2010). Our results for most of the organisms were not significant, possibly due to the small number of organisms with resistant strains. Among the six organisms studied, resistant strains in isolates causing BSI-POA were high for patients admitted from private homes, other hospitals and NHs (31%, 34% and 44%, respectively), $P = 0.002$. Therefore, when patients are admitted with a BSI from these settings, prospective surveillance might be indicated.

Our findings provide new insight into the profiles of patients arriving at the hospital with BSI. Multivariable logistic regression identified seven risk factors that predict BSI-POA. Emergency department staff can utilise these criteria to identify patients with BSI and begin empiric antibiotic therapy sooner. Having specific data about the prevalence of antibiotic resistance among common pathogens in patients arriving from nursing homes and the community can improve the specificity and efficacy of initial antibiotic therapy. Such an approach could notably reduce mortality in patients with bacteraemia (Artero et al., 2010; Yang et al., 2013).

Limitations

Although this study included a large sample, it had limitations. Definitions for infections were based on validated electronic algorithms, which did not include data on patient symptoms. The retrospective nature of the study precluded the collection of some clinical data such as dosage, timeliness and appropriateness of previously prescribed antibiotics or smoking history, which might have resulted in confounding. Moreover, observations lacking admission source were not included. Our data contained information on the six most common organisms in these study sites; hence, we were unable to examine other organisms, which might have impacted the results of the study. Furthermore, our sample was from hospitals in one metropolitan region, so results might not be generalisable to rural communities.

Conclusion

Shifts in healthcare delivery with much higher levels of complex medical care being delivered in the community might have contributed to the dissemination of resistant organisms and hospital-acquired infections into the community (Johannes, 2008). Therefore, the ability to identify risk factors associated with antimicrobial resistance is critical and this information could be used to improve treatment

decisions and decrease the rate of inappropriate antibiotic administration.

Declaration of conflicting interests

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Peer review statement

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