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Trends in Mortality, Length of Stay, and Hospital Charges Associated with Healthcare-associated Infections, 2006–2012

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Abstract

Background—Many factors associated with hospital acquired infections (HAIs) -- including reimbursement policies, drug prices, practice patterns, and the distribution of organisms causing infections -- change over time. We examined whether outcomes, including mortality, length of stay (LOS), daily charges, and total charges associated with HAIs, changed during 2006–2012.

Methods—Electronic data on adults discharged from two tertiary/quaternary and one community hospital during 2006–2012 were collected retrospectively. Computerized algorithms identified infections using laboratory and administrative codes. Propensity scores were used to match cases with uninfected controls. Differences in mortality, LOS, daily charges, and total charges were modeled against infection status and time period (2006–2008 vs. 2009–2012), including interaction for infection status by time period.

Results—Among 352,077 discharges, 24,466 HAIs were detected. There was no significant change in mortality. LOS declined only for bloodstream infections (3 day reduction; $p < 0.01$). Daily charges rose 4% for urinary tract infections but did not change significantly for other HAIs. Total charges declined by 11% for bloodstream infections and 13% for pneumonia.

Conclusions—We found no appreciable or consistent improvement in HAI mortality or LOS during 2006–2012. Costs of bloodstream infections and pneumonia have declined, with most of the change occurring before 2008.

Keywords

Healthcare-associated infections; value-based purchasing

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Conflicts of interest: None.

INTRODUCTION

More than 700,000 healthcare-associated infections (HAIs) occur annually in the United States, resulting in direct costs to hospitals of up to \$45 billion dollars.[1,2] Many studies have examined the costs associated with HAIs, but comparisons among estimates are challenging. Studies vary considerably according to the type of infection (e.g., body site, organism, sensitivity to antimicrobial agents), patient characteristics (e.g., age, underlying medical conditions, severity of illness), and type of healthcare facility (e.g., inpatient vs. outpatient, acute vs. long-term care) considered.[3] Differences in methodology across studies, particularly in the selection of controls and in the payer perspective, also contribute to variation among estimates.[4] Among the most recent studies to estimate the cost of an HAI,[5–11] results ranged from approximately \$10,000 for women who developed surgical site infections (SSI) after undergoing caesarian sections[9] to over \$80,000 for patients who developed catheter-related bloodstream infections (BSI) while in the intensive care unit (ICU).[5]

This variation across studies both in methodology and patient case mix make it difficult to evaluate whether costs and outcomes associated with HAIs have changed over time. Yet there are at least three reasons to believe that the relative costs and outcomes of treating HAIs might change over time and that an estimate of this change is warranted.

First, costs may increase or decrease due to changes in the availability and price of therapies. For example, antibiotics lose patent protection and new antibiotics are introduced – in each case, changing the cost of treatment. In 2006, Zithromax (azithromycin) lost patent protection and in 2008, Maxipime (cefepime) lost its patent protection. In both cases, the price of these antibiotics declined by over 60%.[12] Over the same period, the price of two commonly used antibiotics that remained on patent, daptomycin and linezolid, rose by over 60%.

Second, practice patterns could change over time, either through the evolution of best practices or because of changes in incentives associated with reimbursement mechanisms. Such evidence-based or payment-driven incentives might lead hospitals to alter their behavior, encouraging them to reduce or prolong length of stay (LOS) or to treat patients more or less intensively.[13] For example, in October 2008, as part of a broader value-based purchasing initiative, the Centers for Medicare and Medicaid Services (CMS) stopped allowing hospitals to collect additional payments for patients because they were diagnosed with selected hospital-acquired conditions including catheter-associated urinary tract infections (UTI), vascular catheter-associated infections (BSI), and certain SSI, with the goal of encouraging hospitals to take precautions so that fewer infections would occur.[14,15] This initiative, which in effect reduced the level of reimbursement for some patients with infections, might also have led hospitals to alter the costs of caring for patients with or at risk for these infections, through changes in practices around cultures, screening, or medications.[15] Several other initiatives aimed at changing care patterns likewise may have altered hospital behaviors.[13]

Finally, costs and outcomes might also change because of changes in the profile of infections themselves. Changes in the causative organisms or in their susceptibility to antibiotic treatment might alter the pattern of costs or outcomes over time. The purpose of this study was to use a consistent methodology and dataset to determine whether mortality, LOS, charges per hospital day, and total charges associated with HAIs have changed over the 2006–2012 period.

METHODS

Sample and Setting

Data were obtained retrospectively for all patients discharged from three hospitals within a single New York City network from January 1, 2006 through December 31, 2012. The facilities include a 221-bed community hospital, a 647-bed adult tertiary/quaternary care hospital, and a 914-bed adult pediatric and adult tertiary/quaternary care hospital. This study was approved by the institutional review boards of the study institutions.

Data Collection

Data were collected from patients' electronic medical records and other digital sources including the admission-discharge transfer system, the cost accounting system, the perioperative record keeping system, and the clinical data warehouse, which stores information from a variety of smaller systems (e.g., laboratory and medication administration records). Specific data elements extracted from these systems included all International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure and diagnosis codes, time-stamped records of all microbiologic cultures, medications administered, procedures performed, and presence of indwelling catheters or devices, and itemized and total charges for the hospitalization. The process of collecting and linking these electronic data has been described in detail previously.[16]

HAIs were identified using previously validated electronic algorithms derived from the Centers for Disease Control and Prevention National Healthcare Safety Network (NHSN) surveillance definitions.[16–18] The algorithms used a combination of microbiologic culture results, urine microscopy, and ICD-9-CM procedure and diagnosis codes to identify four types of infection: BSI, UTI, SSI, and pneumonia. For each of these four infection types, patient discharges were classified as either 'infected' or 'uninfected.' In order to reduce misclassification, patient discharges were considered 'indeterminate' if infection status could not be definitively assessed based on the available electronic data. Patient discharges classified as indeterminate were excluded from the analysis. Notably, we did not rely on billing codes to identify HAIs.[19] Infections occurring on or after the third day of hospitalization were considered healthcare-associated. Some HAIs can initially manifest up to 30 days following exposure; patients readmitted within 30 days might have been infected in the initial or subsequent hospitalization. We excluded these patients from the analysis.

To control for changes in the causative organisms and in resistance, we classified infections as associated with the following causative organisms: *Staphylococcus aureus*, *Enterococcus faecalis*, *Enterococcus faecium*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and

Acinetobacter baumannii. We defined antimicrobial resistance using algorithms we have reported previously.[20]

Statistical Analysis

We separated time-varying factors (including medications, central venous catheterization, urinary catheterization, and surgical procedures; see Appendix I) into pre- and post-infection components. Propensity scores were used to match cases with uninfected controls in order to estimate differences in mortality, total LOS, and total hospital charges between patients who developed an HAI versus those who did not. Our data do not include date-specific charges. To avoid the overestimate of the costs of HAI that might occur without such data, we use exact matching by date of infection, as suggested by Nelson et al., and include a more extensive range of time-varying covariates in the pre-infection period than used in Nelson et al.'s prior study.[21]

Discrete time survival models for developing a BSI, UTI, SSI, or pneumonia on a given day of hospitalization were estimated separately, allowing for a nonparametric hazard and controlling for a variety of time-invariant factors including age, gender, month and year of hospitalization, and ICD-9-CM-captured diagnoses, as well as pre-infection time-varying covariates.[20] Each patient discharge contributed one observation for every day they remained in the hospital, beginning on day four and ending on the day of infection, discharge, or death. One control was selected for each case based on both the propensity score generated by this model (using nearest neighbor matching) and the exact day of hospitalization on which the infection occurred (exact matching).

Percent mortality, mean LOS, mean daily hospital charges, mean total hospital charges, and characteristics of cases and controls were calculated for each infection type before and after matching. T-tests were used to assess whether differences in these outcomes were different for cases and controls over the full 7 year period.

In calculating mean daily and total charges, we adjusted for the effects of inflation over time using the Consumer Price Index and report all dollar figures in 2012 dollars. In regression analyses of daily and total charges, we log-transformed charges to address the skewness of the charge distribution.[22] Because the propensity score used to match the data includes the month and year of hospitalization, we do not further adjust the charge data for inflation. Instead, we report percentage differences in charges (which, by construction, are the same as percentage differences in costs), rather than absolute differences.

To assess whether these differences in mortality, LOS, daily charges or total charges changed over time, logistic or log linear regression was used to model these outcomes against infection status and year, including interaction terms for infection status by year. The coefficients on interaction and year terms (and confidence intervals) were plotted. Each infection type was modeled separately, controlling for the following factors: case's infecting organism and antimicrobial susceptibility; patient characteristics including age, sex, Charlson Comorbidity Index, Clinical Classifications Software (CCS) category, and admission hospital; history or presence of diabetes mellitus, malignancies, renal failure, chronic dermatitis, trauma, wound, transplant, burns, stay in skilled nursing facility,

substance abuse, mechanical ventilation, intubation, and dialysis; number of days with central venous catheter, urinary catheter, ICU stay, and receipt of high risk medication; and receipt of general anesthesia, operating room procedure, major procedure >30 minutes, venous catheter, and high-risk medication prior to infection (for cases) or day of match (for controls).

To assess whether differences in mortality, LOS, hospital charges per day, and total hospital charges varied between the beginning and end of the period, logistic or log linear regression was used to model these outcomes against infection status and time period (2006–2008 vs. 2009–2012), including interaction terms for infection status by time period. To assess whether changes in the profiles of organisms and antibiotic resistance among infected cases affected outcomes over time, we omitted controls for the infecting organism and whether the organism was resistant to antibiotics in sensitivity analyses.

RESULTS

A total of 24,466 HAIs were detected among the 352,077 adult discharges that occurred across the three hospitals during the study period. Unadjusted mortality, length of stay, daily hospital charges, and total hospital charges in the matched samples are described in Table 1. The demographic and clinical characteristics of patients in the unmatched and matched samples are available in Appendix 1. After matching, mortality rates for infected patients were significantly higher for infected than for uninfected patients, for those infected with UTI, BSI, and SSI. Charges per day were not statistically significantly different for infected and uninfected patients, except in the case of hospital-acquired pneumonia, where patients with infections had daily charges \$343 lower ($p<0.01$) than did matched patients without infections. The main differences between infected and uninfected patients occurred through LOS. For each infection type, infected patients had statistically significantly longer hospital stays (3.9–6.6 days longer) than their matched uninfected counterparts. These longer stays translated into statistically significantly higher total charges, ranging from \$34,394 in higher charges for BSI patients to \$78,585 higher charges for pneumonia patients.

We next conducted regression-adjusted analyses, including interaction terms by year. We report regression-adjusted estimates of annual rates and trends for length of stay, daily charges, and total charges in figures 1–4 (data for these figures are in Appendix Table 2). After adjusting for covariates, we find that mortality for patients with BSI and SSI was statistically significantly higher at baseline. We find that at baseline (2006), covariate-adjusted length of stay was statistically significantly longer for patients with BSI (4.6 days) or pneumonia infections (6.9 days) than for matched patients. Daily charges were about 10% higher ($p<0.001$) for patients with BSI or pneumonia than for matched patients. Total charges for patients with infections were about higher 15% for UTI and SSI, about 29% higher for BSI, and about 43% higher for pneumonia than for similar patients without HAIs ($p<0.001$).

There are no significant trends in LOS or mortality for any of the infection types. Charges per day for both BSI and pneumonia were significantly lower throughout the period after 2006 than in 2006 (these differences are statistically significant except in 2012), and SSI

charges per day also declined (though not statistically significantly) over time, while charges per day for UTI were generally (and sometimes statistically significantly) higher from 2009 on than earlier. These differences in charges per day are reflected in declines in total charges for BSI and pneumonia over the period. By 2012, charges for infected relative to uninfected patients with BSI, SSI, and pneumonia were all about 13% lower than they had been in 2006 (statistically significant for BSI and pneumonia, except in 2012). Combining the baseline and trend results, by 2012, total charges for patients with BSI were about 15% higher than for matched controls; charges for patients with pneumonia were about 30% higher than for matched controls; charges for UTI were about 14% higher for matched controls (no change from 2006); and charges for patients with SSI were no longer statistically different from those of matched controls.

compares outcomes between the earlier period (2006–2008) and the later period (2009–2012). There was no significant change in HAI mortality between the earlier and later period. Length of stay for 3 of the 4 infection types saw no statistically significant change (relative to uninfected controls), but LOS for BSI infections averaged 3 days less in the later period than in the earlier period ($p<0.01$). Hospital charges per day rose by nearly 4% relative to controls for UTI, but did not change significantly for other HAI types. Finally, total hospital charges, relative to controls, declined by 11% for BSI and 13% for pneumonia between the 2006–2008 and 2009–2012 periods.

In sensitivity analyses, we repeated the regressions omitting controls for organisms and resistance. The time trends we observed for charges were not affected by this specification change, suggesting that changes in the profile of infections and resistance did not contribute to changes in charges over time.

DISCUSSION

The results of this study suggest that relatively little has changed in either the profile of infection types or the treatment of patients with HAI since 2006. There has been no appreciable improvement in mortality for any of the four infections over this period and length of stay has not changed in a consistent way relative to that for patients without infections. This pattern suggests that changes in incentives, such as those associated with the CMS payment change in 2008, have not altered the ways that hospitals care for patients after they contract a hospital-acquired infection. Omitting controls for causative organism and resistance had little effect on these patterns.

In contrast to this pattern of little change in hospital behavior, the costs of treating both BSI and pneumonia, relative to matched controls, appears to have declined over time, with part of the decline occurring through a reduction in charges per day. One component of this reduction in the hospital's costs of treating these conditions may have been the reduction in the price of medications frequently used in their treatment. While reductions in medication costs are welcome, these reductions in cost also reflect the lack of progress in developing newer antibiotics to treat HAI more effectively.

The lack of progress in treatment and outcomes increases the importance of reducing the prevalence of these conditions. That was the goal of CMS's 2008 payment policy change, as well as of multiple other initiatives.[23–25] To the extent that these policy and practice changes disproportionately prevented infections in patients who were comparatively healthier in ways that we could not control in these data, the trends in outcomes over time that we observed could be confounded by changes in the characteristics of patients acquiring infections.

Healthcare acquired infections remain a problem with substantial human and financial costs. Lengths of stay for many of these patients remain significantly longer than for matched controls. While by 2012, daily charges for patients with infections were no longer significantly higher than for patients without infections, total charges per case for all four infections remained significantly higher than charges for matched patients even at the end of this period (15% and 30% higher respectively in 2012). Furthermore, our estimates of excess charges associated with HAIs were produced using a conservative methodology, accounting for time-dependent bias by matching on length of stay prior to infection and multiple pre-infection covariates.[21] Healthcare infections disproportionately affect patients with many comorbidities, and, as the high charges associated with our matched sample show, these cases are always relatively expensive. In urban New York hospitals, the cost-to-charge ratio averages 0.327. Combining this figure with our estimates of charges implies that in 2012, the cost per infected patient in New York hospitals was about \$10,000 higher than the cost for a similar patient who had not contracted a HAI. These high costs suggest that there may be infection control practices that would be cost-saving at the societal level.

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Appendix I

Appendix Table 1

Patient characteristics and covariate balance in matched sample

	Unmatched		Matched	
	Infected	Uninfected	Infected	Uninfected
Urinary tract infection sample	N=13,153	N=315,925	N=8,058	N=8,049
% female sex	62.5	55.1	60.1	67.4
Mean (SD) age in years	65.9 (17.4)	57.5 (19.9)	65.0 (17.6)	67.3 (16.2)
% with ICU stay	46.4	16.0	47.4	45.4
Mean (SD) days in ICU	6.4 (17.1)	0.8 (3.5)	7.0 (18.9)	5.3 (12.0)
% with urinary catheter	78.6	47.0	77.3	78.4
Mean (SD) days with urinary catheter	13.9 (21.6)	2.4 (5.3)	13.3 (21.4)	11.6 (19.0)
% with central venous catheter	41.9	14.8	42.2	39.8
Mean (SD) days with central venous catheter	9.0 (23.2)	1.1 (4.8)	9.1 (24.4)	6.9 (15.4)
% underwent operating room procedure 30 minutes	35.0	21.1	37.5	37.2
Mean (SD) Charlson Comorbidity Index	2.9 (2.6)	1.9 (2.4)	2.7 (2.6)	2.8 (2.7)
Mean (SD) 3M Severity of Illness	3.2 (0.8)	2.3 (0.9)	3.1 (0.8)	3.0 (1.0)
Bloodstream infection sample	N=5,837	N=332,824	N=3,611	N=3,603
% female sex	42.2	56.5	42.5	40.6
Mean (SD) age in years	61.5 (17.2)	58.1 (20.0)	61.6 (17.3)	62.8 (16.4)
% with ICU stay	59.7	15.6	59.3	54.4
Mean (SD) days in ICU	10.6 (21.1)	0.7 (3.3)	11.2 (24.6)	9.8 (17.3)
% with urinary catheter	72.0	47.4	73.2	76.7
Mean (SD) days with urinary catheter	17.2 (26.3)	2.5 (5.4)	18.0 (27.1)	17.1 (21.4)
% with central venous catheter	61.1	14.2	59.1	59.3
Mean (SD) days with central venous catheter	16.7 (30.3)	1.0 (4.4)	16.0 (29.9)	14.7 (25.1)
% underwent operating room procedure 30 minutes	29.5	21.6	33.3	36.7
Mean (SD) Charlson Comorbidity Index	3.2 (2.7)	1.9 (2.4)	3.1 (2.7)	3.4 (2.8)
Mean (SD) 3M Severity of Illness	3.5 (0.7)	2.3 (0.9)	3.5 (0.7)	3.4 (0.8)
Surgical site infection sample	N=1,776	N=108,558	N=1,296	N=1,293
% female sex	43.5	58.4	41.0	43.3
Mean (SD) age in years	59.6	56.6 (19.0)	59.8 (17.1)	59.6 (17.7)
% with ICU stay	51.8	23.9	55.3	50.0
Mean (SD) days in ICU	9.3 (20.8)	1.2 (5.1)	10.2 (20.8)	7.8 (16.4)
% with urinary catheter	82.2	7.6	85.0	83.2
Mean (SD) days with urinary catheter	18.2 (26.2)	4.3 (7.2)	19.0 (25.8)	15.7 (21.2)
% with central venous catheter	57.7	25.0	59.5	49.9
Mean (SD) days with central venous catheter	15.0 (27.3)	1.8 (7.3)	16.0 (30.0)	11.5 (20.4)
% underwent operating room procedure 30 minutes	67.1	51.2	71.4	68.1
Mean (SD) Charlson Comorbidity Index	2.6 (2.6)	1.7 (2.2)	2.6 (2.6)	2.7 (2.5)
Mean (SD) 3M Severity of Illness	3.3 (0.8)	2.2 (1.0)	3.3 (0.8)	3.2 (0.9)
Pneumonia sample	N=3,700	N=320,244	N=2,014	N=2,010

	Unmatched		Matched	
	Infected	Uninfected	Infected	Uninfected
% female sex	39.6	56.8	44.8	41.8
Mean (SD) age in years	64.5 (17.1)	57.7 (20.0)	64.2 (17.0)	67.0 (16.3)
% with ICU stay	79.7	15.4	43.0	83.5
Mean (SD) days in ICU	17.9 (25.6)	0.7 (3.2)	16.4 (22.6)	12.0 (13.7)
% with urinary catheter	82.3	47.8	40.0	86.5
Mean (SD) days with urinary catheter	23.7 (28.4)	2.4 (5.4)	22.6 (27.6)	20.2 (21.6)
% with central venous catheter	71.5	14.4	68.0	75.3
Mean (SD) days with central venous catheter	20.3 (29.3)	1.0 (4.8)	18.6 (27.1)	14.1 (20.2)
% underwent operating room procedure 30 minutes	40.7	21.9	42.0	41.7
Mean (SD) Charlson Comorbidity Index	3.0 (2.5)	1.9 (2.3)	3.0 (2.5)	2.8 (2.5)
Mean (SD) 3M Severity of Illness	3.8 (0.4)	2.3 (0.9)	3.8 (0.5)	3.7 (0.6)

Propensity score model included sex, age in five year intervals; year and month of admission; hospital; organism; infection site; prior hospitalization; diabetes; chronic dermatitis; trauma; wounds; burns; prior stay in a skilled nursing facility; renal failure; history of substance abuse; having 1 hospital roommate; Agency for Healthcare Research and Quality Clinical Classifications Software (CCS) categories; use of and number of days of use of chemotherapeutic, immunosuppressive, and anti-inflammatory medications; mechanical ventilation; urinary, central venous, or cardiac catheterization; catheter angiography; vascular stenting; dialysis; surgical procedure; general anesthesia; intubation; intensive care unit stay; and day of hospital stay on which the infection occurred.

Appendix Table 2

Changes in mortality, length of stay, total hospital charges, and charges per day attributable to healthcare-associated infections, 2006–2012

Outcome ^a Infection	2006		2007		2008		2009		2010		2011		2012	
	B ^b	P	B ^b	P	B ^b	P	B ^b	P	B ^b	P	B ^b	P	B ^b	P
Mortality ^c														
UTI	1.22	0.22	0.68	0.08	1.17	0.52	1.36	0.22	1.09	0.70	1.01	0.95	0.80	0.40
BSI	3.78	<0.001**	1.49	0.18	1.22	0.50	2.64	0.005**	0.84	0.54	0.55	0.04	1.23	0.51
SSI	2.56	0.02	0.55	0.28	1.14	0.81	0.46	0.19	1.02	0.97	0.43	0.17	0.26	0.06
PNU	1.63	0.03	0.75	0.35	0.80	0.49	0.57	0.08	0.52	0.05	0.73	0.34	1.02	0.97
LOS ^c														
UTI	1.38	0.13	−0.53	0.67	2.69	0.04	0.02	0.98	0.52	0.69	0.59	0.66	0.34	0.81
BSI	4.55	0.001**	2.44	0.20	0.52	0.78	−2.27	0.25	−0.81	0.67	−0.87	0.66	−3.87	0.06
SSI	2.24	0.30	−3.29	0.30	−0.57	0.86	−2.51	0.44	1.40	0.67	−4.96	0.15	−4.27	0.21
PNU	6.89	<0.001**	2.12	0.43	−0.07	0.98	0.23	0.93	2.60	0.37	−4.04	0.16	−2.30	0.45
Charges ^{d,e}														
UTI	0.15	<0.001**	−0.06	0.07	−0.01	0.84	−0.01	0.85	−0.03	0.36	0.05	0.21	−0.01	0.77
BSI	0.29	<0.001**	−0.03	0.52	−0.05	0.38	−0.11	0.04	−0.13	0.02	−0.16	0.005*	−0.14	0.01
SSI	0.14	0.01	−0.09	0.26	−0.02	0.81	−0.10	0.20	−0.02	0.81	−0.09	0.28	−0.12	0.16
PNU	0.43	<0.001**	−0.02	0.72	−0.17	0.01	−0.20	0.003*	−0.17	0.02	−0.27	<0.001**	−0.12	0.13
Charges per day ^{d,e}														
UTI	−0.01	0.52	0.004	0.82	−0.04	0.02	0.04	0.04	−0.001	0.97	0.06	0.001**	0.006	0.77
BSI	0.10	<0.001**	−0.08	<0.001**	−0.08	0.001**	−0.07	0.01*	−0.07	0.004*	−0.11	<0.001**	−0.05	0.06
SSI	0.008	0.73	0.007	0.83	0.02	0.65	0.02	0.56	−0.03	0.04	−0.003	0.93	−0.04	0.29

Outcome ^a Infection	2006		2007		2008		2009		2010		2011		2012	
	B ^b	P	B ^b	P	B ^b	P	B ^b	P	B ^b	P	B ^b	P	B ^b	P
PNU	0.10	<0.001**	-0.07	0.02	-0.1	<0.001**	-0.07	0.04	-0.11	0.002*	-0.11	0.001**	-0.05	0.18

LOS, length of stay; UTI, urinary tract infection; BSI, bloodstream infection; SSI, surgical site infection; PNU, pneumonia.

^aReference year 2006. Models control for infection status, case's infecting organism and antimicrobial susceptibility; patient characteristics including age, sex, Charlson Comorbidity Index, Agency for Healthcare Research and Quality Clinical Classifications Software (CCS) category, and admission hospital; history or presence of diabetes mellitus, malignancies, renal failure, chronic dermatitis, trauma, wound, transplant, burns, stay in skilled nursing facility, substance abuse, mechanical ventilation, intubation, and dialysis; number of days with central venous catheter, urinary catheter, intensive care unit stay, and receipt of high risk medication; and receipt of general anesthesia, operating room procedure, major procedure >30 minutes, venous catheter, and high-risk medication prior to infection (for cases) or day of match (for controls).

^bOdds ratios are reported for mortality models.

^cMultiple logistic regression.

^dMultiple linear regression.

^eDependent variable is natural log of total hospital charges or charges per day.

*p<0.01;

**p<0.001.

Figure 1. Trends in Mortality, Length of Stay, Charges per Day, and Total Charges, relative to Matched Controls, 2006–2012

Models control for infection status, case's infecting organism and antimicrobial susceptibility; patient characteristics including age, sex, Charlson Comorbidity Index, Clinical Classifications Software (CCS) category, and admission hospital; history or presence of diabetes mellitus, malignancies, renal failure, chronic dermatitis, trauma, wound, transplant, burns, stay in skilled nursing facility, substance abuse, mechanical ventilation, intubation, and dialysis; number of days with central venous catheter, urinary catheter, intensive care unit stay, and receipt of high risk medication; and receipt of general anesthesia, operating room procedure, major procedure >30 minutes, venous catheter, and high-risk medication prior to infection (for cases) or day of match (for controls). Dotted lines indicate 99% confidence interval.

(A) Length of Stay – Days Compared to Matched Controls

(B) Charges per Day – Percentage Difference Relative to Matched Controls

(C) Total Charges – Percentage Difference Relative to Matched Controls

(D) Mortality – Odds Relative to Matched Controls

Table 1

Characteristics of matched infected and uninfected samples

	Infected	Uninfected	Difference of means between infected and uninfected (t-test)
Urinary tract infection sample	N=8,048	N=8,048	
% in-hospital mortality	9.1	7.1	2.0 **
Mean (SD) length of stay in days	26.0 (29.5)	22.1 (28.9)	3.9 **
Mean (SD) total charges in US 2012 dollars	\$238,940 (343,218)	\$197,225 (249,539)	41,715 **
Mean (SD) charges per day in US 2012 dollars	\$8546 (3365)	8652 (3504)	-106
Bloodstream infection sample	N=3,603	N=3,603	
% in-hospital mortality	21.4	8.6	12.8 **
Mean (SD) length of stay in days	36.2 (34.8)	32.2 (29.0)	4.0 **
Mean (SD) total charges in 2012 US dollars	\$349,398 (412,348)	\$315,004 (334,982)	34,394 **
Mean (SD) charges per day in 2012 US dollars	\$9127 (3702)	\$9239 (3659)	-112
Surgical site infection sample	N=1,292	N=1,292	
% in-hospital mortality	11.7	6.7	5.0 **
Mean (SD) length of stay in days	34.3 (34.4)	29.6 (28.1)	4.7 **
Mean (SD) total charges in 2012 US dollars	\$362,006 (426,341)	\$292,380 (302,807)	69,626 **
Mean (SD) charges per day in 2012 US dollars	\$9669 (3710)	9727 (3818)	-58
Pneumonia sample	N=2,010	N=2,010	
% in-hospital mortality	22.3	23.0	-0.7
Mean (SD) length of stay in days	38.5 (33.0)	31.9 (27.9)	6.6 **
Mean (SD) total charges in 2012 US dollars	\$414,876 (390,426)	\$336,291 (296,234)	78,585 **
Mean (SD) charges per day in 2012 US dollars	\$10572 (3970)	\$10914 (4198)	-342 **

**
p<0.01

Table 2

Mortality, length of stay, hospital charges per day, and total hospital charges attributable to healthcare-associated infections, 2009–2012 versus 2006–2008

	UTI		BSI		SSI		PNU	
	B ^a	P	B ^a	P	B ^a	P	B ^a	P
Mortality ^b	1.18	0.232	0.81	0.205	0.57	0.098	0.78	0.175
LOS ^c	-0.283	0.694	-2.841	0.007 ^{**}	-1.231	0.501	-1.594	0.288
Charges per day ^{c,d}	0.037	<0.001 ^{**}	-0.023	0.081	-0.02	0.319	-0.024	0.175
Charges ^{c,d}	0.023	0.227	-0.109	<0.001 ^{**}	-0.04	0.369	-0.132	<0.001 ^{**}

LOS, length of stay; UTI, urinary tract infection; BSI, bloodstream infection; SSI, surgical site infection; PNU, pneumonia.

Models control for infection status, case's infecting organism and antimicrobial susceptibility; patient characteristics including age, sex, Charlson Comorbidity Index, Clinical Classifications Software (CCS) category, and admission hospital; history or presence of diabetes mellitus, malignancies, renal failure, chronic dermatitis, trauma, wound, transplant, burns, stay in skilled nursing facility, substance abuse, mechanical ventilation, intubation, and dialysis; number of days with central venous catheter, intensive care unit stay, and receipt of high risk medication; and receipt of general anesthesia, operating room procedure, major procedure >30 minutes, venous catheter, and high-risk medication prior to infection (for cases) or day of match (for controls).

^aOdds ratios are reported for mortality models.

^bMultiple logistic regression

^cMultiple linear regression

^dDependent variable is natural log of total hospital charges or charges per day.

^{**}p<0.01