Risk Factors for Urinary Tract Infections in Cardiac Surgical Patients

Jacob R. Gillen, James M. Isbell, Alex D. Michaels, Christine L. Lau, and Robert G. Sawyer

Abstract

Background: Risk factors for catheter-associated urinary tract infections (CAUTIs) in patients undergoing non-cardiac surgical procedures have been well documented. However, the variables associated with CAUTIs in the cardiac surgical population have not been clearly defined. Therefore, the purpose of this study was to investigate risk factors associated with CAUTIs in patients undergoing cardiac procedures.

Methods: All patients undergoing cardiac surgery at a single institution from 2006 through 2012 (4,883 patients) were reviewed. Patients with U.S. Centers for Disease Control (CDC) criteria for CAUTI were identified from the hospital's Quality Assessment database. Pre-operative, operative, and post-operative patient factors were evaluated. Univariate and multivariable analyses were used to identify significant correlations between perioperative characteristics and CAUTIs.

Results: There were 55 (1.1%) documented CAUTIs in the study population. On univariate analysis, older age, female gender, diabetes mellitus, cardiogenic shock, urgent or emergent operation, packed red blood cell (PRBC) units transfused, and intensive care unit length of stay (ICU LOS) were all significantly associated with CAUTI [$p < 0.05$]. On multivariable logistic regression, older age, female gender, diabetes mellitus, and ICU LOS remained significantly associated with CAUTI. Additionally, there was a significant association between CAUTI and 30-d mortality on univariate analysis. However, when controlling for common predictors of operative mortality on multivariable analysis, CAUTI was no longer associated with mortality.

Conclusions: There are several identifiable risk factors for CAUTI in patients undergoing cardiac procedures. CAUTI is not independently associated with increased mortality, but it does serve as a marker of sicker patients more likely to die from other comorbidities or complications. Therefore, awareness of the high-risk nature of these patients should lead to increased diligence and may help to improve peri-operative outcomes. Recognizing patients at high risk for CAUTI may lead to improved measures to decrease CAUTI rates within this population.

HOSPITAL-ACQUIRED INFECTIONS are a significant cause of patient morbidity and hospital cost in our health care system [1–3]. Factors that increase the risk of hospital-acquired infections, in particular catheter-associated urinary tract infections (CAUTIs), have been well documented in medical patients and in many types of surgical patients. These risk factors include older age, female gender, diabetes mellitus, and greater length of time with urinary catheter in place [4–6]. Other associations, such as peri-operative blood transfusions and peak urine flow rates, have also been reported [7,8]. Additionally, risk factors for nosocomial infections in general within cardiac surgical patients have been presented [9–11]. However, factors associated with CAUTIs

in cardiac surgical patients have not been clearly defined. Additionally, the impact of CAUTIs on mortality in this population is not known.

In light of these gaps, the purpose of the present study was to identify peri-operative predictors of CAUTI infection within the cardiac surgical patient population. The primary hypothesis was that certain patient and procedural characteristics, such as gender, emergent case status, blood products transfused, and length of time with Foley catheter in place, would be associated with an increased incidence of CAUTI. The secondary hypothesis was that there would be a significant association between CAUTI and 30-d patient mortality.

Patients and Methods

Patients and data acquisition

Patient data were acquired via three sources: 1) the Society of Thoracic Surgeons (STS) database (which does not contain CAUTI data), 2) our institution's Quality Assessment (QA) database (CAUTI data), and 3) chart review.

First, the STS database was queried for data on all cardiac surgery patients at our institution between January 2006 and September 2012. Data on pre-operative risk factors, operative features, and post-operative events for these patients were collected, utilizing current STS definitions for the variables examined [12].

Second, our institution's QA database was reviewed to identify cardiac surgical patients who had a diagnosis of hospital-acquired CAUTIs over this same time period. The definition of CAUTI (also known as symptomatic urinary tract infection [UTI] in previous definition schemes) is based on the U.S. Center for Disease Control (CDC) guidelines, last updated in 2010 [13]. Therefore, all CAUTI patients were symptomatic (febrile or urinary symptoms) by definition; cases of asymptomatic bacteriuria were not included.

Of note, our institution did not routinely collect CAUTI data from patients on the cardiac surgical floor prior to October 2010. However, some CAUTIs from floor patients were identified and entered into the QA database due to surveillance for resistant bacterial organisms. CAUTI data from ICU patients were consistently collected throughout the study period.

Next, patient data from the STS database and CAUTI data from the QA database were merged. Lastly, patient charts were reviewed for number of days with Foley catheter in place and for CAUTI pathogen in the CAUTI patient cohort. Of note, Foley catheter data were only reliably documented in patients beginning in April 2011, so patients with Foley catheter data represent a subcohort within our entire study population. Additionally, because of the large number of non-CAUTI patients relative to CAUTI patients, a random sampling of every tenth non-CAUTI patient was used for the Foley catheter time review.

At our institution, the majority of our patients are catheterized in the operating room prior to their cardiac surgery, with peri-operative antibiotic administration typically occurring after Foley catheter placement. Post-operatively, we have used a protocol since 2010 for early removal of urinary catheters, calling for removal of catheters by post-operative day 2 unless there are specific indications for continued catheter presence, such as accurate urine output recordings in critically ill patients or urinary retention. However, prior to 2010, urinary catheter removal was less regimented.

Statistical analysis

The primary aim was to identify independent predictors of post-operative CAUTI following cardiac surgery. A secondary aim was to determine if there was a significant association between post-operative CAUTI and 30-day mortality. Continuous variables are reported as median and interquartile range (25th to 75th percentiles), and categorical variables are expressed as percentage of the total study population. Univariate analyses for the outcome of CAUTI included Pearson chi-square or Fisher exact test, as appro-

priate, for categorical variable comparisons, whereas the Mann-Whitney *U* test was used to compare continuous data. Two multiple logistic regressions were performed: One to identify independent predictors of CAUTI and a second to determine the association between CAUTI and 30-d mortality after adjusting for the confounding influence of various patient and operation-related risk factors. All pre-operative variables entered as covariates were selected a priori on the basis of established clinical risks for CAUTI and for cardiac surgery-related mortality. Odds ratios (ORs) with a 95% confidence interval (CI) are used to report the results of logistic regression modeling. Model performance was assessed by the Hosmer-Lemeshow goodness of fit test and by evaluating the area under the receiver operating characteristics curve (AUC). Reported *p* values are 2-tailed with an $\alpha < 0.05$. Data manipulation and analysis were performed using IBM SPSS Statistics for Windows, Version 20 (IBM Corporation, Armonk, NY).

Results

Risk factors for UTI

A total of 4,883 patients underwent cardiac operations between 2006 and 2012. Within this cohort, there were 64 documented CAUTIs in 55 patients (1.1% of all cardiac patients). The most common pathogens were *Candida albicans*, *Enterobacter cloacae*, and *Escherichia coli* (Table 1). Among documented CAUTIs, 17 (26.6%) were fungal and 47 (73.4%) were bacterial. Days to recognition of UTI ranged from 1 to 70, with median of 8 and interquartile range of five to 11 days.

There was no significant difference between CAUTI rate before and after October 2010 (1.1% vs. 1.2%, $p = 0.77$), the time point at which routine catheter removal at 48 h post-operatively became standard at our institution. Ten of 55 patients were receiving anti-microbials at the time of UTI diagnosis, all outside of the standard surgical prophylaxis period (24 h of intravenous cephazolin throughout the study period). During the period in which data on floor patients were collected, there were three CAUTIs in floor patients and 15 in ICU patients. Two of these three floor patients had documented repeat Foley catheterization after initial removal; there were no reinsertions documented in the ICU patients.

Univariate analyses between perioperative factors and CAUTIs are displayed in Table 2. Among pre-operative patient characteristics, female gender, diabetes mellitus, cardiogenic shock, older age, and increased STS predicted risk of mortality (PROM) were all significant risk factors for

TABLE 1. MOST COMMON URINARY TRACT INFECTION PATHOGENS

Pathogen	Count
<i>Candida albicans</i>	8
<i>Enterobacter cloacae</i>	7
<i>Escherichia coli</i>	7
<i>Candida glabrata</i>	6
<i>Pseudomonas aeruginosa</i>	5
<i>Klebsiella pneumoniae</i>	4
<i>Proteus mirabilis</i>	4

TABLE 2. SIGNIFICANT ASSOCIATIONS WITH CATHETER-ASSOCIATED URINARY TRACT INFECTION ON UNIVARIATE ANALYSIS

Variable	CAUTI (n=55)	No CAUTI (n=4828)	p
Female gender (%)	63.6	33.1	<0.001
Smoker (%)	32.7	30.6	0.738
Diabetes (%)	49.1	31.2	0.004
Immunosuppression (%)	7.3	4.2	0.292
Renal failure (%)	3.6	1.4	0.371
Cardiogenic shock (%)	16.4	5.4	<0.001
Emergent/Urgent case (%)	58.2	38.8	0.003
Procedure type (%)			0.324
CABG	21.8	31.7	
AVR	7.3	13.7	
AVR + CABG	10.9	6.7	
MV Repair	3.6	3.7	
CABG + MV Repair	3.6	2.2	
MV Replacement	1.8	2.6	
CABG + MV Replacement	1.8	0.7	
AVR + MV Replacement	0.0	0.4	
Other	45.5	30.8	
Deep sternal wound infection (%)	5.5	0.4	0.002
Age (median, years)	71.0	65.0	0.002
BMI (median)	27.8	28.0	0.384
Predicted risk of mortality (median, %)	5.0	1.8	<0.001
PRBCs transfused (median, units)	4.0	1.0	<0.001
ICU LOS (median, days)	9.4	1.9	<0.001
Foley catheter time (median, days)*	8.0	3.0	<0.001
30-d mortality (%)	10.9	3.2	0.001

UTI=urinary tract infection, BMI=body mass index, PRBCs=packed red blood cells, ICU LOS=intensive care unit length of stay, CABG=coronary artery bypass grafts; MV=mitral valve; AVR=aortic valve replacement.

*Foley catheter times were only obtained on 18 CAUTI patients and 100 non-CAUTI patients.

CAUTI. Among operative and post-operative factors, emergent/urgent operations, number of packed red blood cells (PRBCs) transfused, intensive care unit length of stay (ICU LOS), presence of deep sternal wound infection (DSWI) were all significantly correlated with CAUTI as well. As expected, time with Foley catheter was significantly longer in the

TABLE 3. SIGNIFICANT ASSOCIATIONS WITH CATHETER-ASSOCIATED URINARY TRACT INFECTION ON MULTIVARIABLE ANALYSIS

Variable	OR	95% CI	p
Age (years)	1.03	[1.005, 1.055]	0.016
Male gender	0.307	[0.172, 0.547]	<0.001
Diabetes mellitus	2.04	[1.164, 3.575]	0.013
ICU LOS (days)	1.051	[1.037, 1.064]	<0.001
Emergent/Urgent case	1.679	[0.950, 2.966]	0.074

*Model performance: AUC=0.807; Hosmer and Lemeshow Test, p=0.197.

AUC=area under the receiver-operating characteristics curve; OR=odds ratio, CI=confidence interval, ICU LOS=intensive care unit length of stay.

TABLE 4. MULTIVARIABLE RISK-ADJUSTED ASSOCIATIONS WITH MORTALITY

Variable	OR	95% CI	p
Age (years)	1.014	[0.992, 1.036]	0.209
Male gender	0.918	[0.550, 1.534]	0.744
Predicted risk of mortality	21,520	[1721, 269030]	<0.001
Urinary tract infection	2.09	[0.458, 9.528]	0.341

OR=odds ratio, CI=confidence interval.

AUC=0.753; Hosmer and Lemeshow Test, p=0.172.

CAUTI patients (median 8 d, interquartile range 6.5–11) compared with non-CAUTI patients (median 3, interquartile range 3–4). Of note, smoking status, immunosuppressive therapy, pre-operative renal failure, body mass index (BMI), and procedure type were not significantly associated with CAUTI.

Further review of the CAUTI patients with DWSIs (total of three) revealed that all sternal infections were bacterial in nature (*Staphylococcus aureus* x 2 and *Morganella morganii*) and preceded the patients' CAUTI diagnosis. Interestingly, all of these CAUTIs were because of fungal infection (*C. albicans* x 2 and *Candida glabrata*), with no common pathogens between sternal infection and CAUTI in any given patient.

Results of the multivariable logistic regression between perioperative risk factors and CAUTIs are presented in Table 3. In this model, older age, diabetes mellitus, and ICU LOS all remained significantly associated with CAUTI, whereas male gender was protective against CAUTI. With each year increase in patient age, risk of CAUTI increased by 3.0%, whereas each day in the ICU increased the risk of CAUTI by 5.1%.

Urinary tract infection and mortality

Among the 55 patients with documented CAUTIs, there were six deaths (10.9%). Urosepsis was not the cause of death in any of these patients. The mortality rate in CAUTI patients was significantly greater than the rate in non-CAUTI patients (10.9% vs. 3.2%, p=0.001; Table 2). However, after controlling for age, gender, and STS PROM on multivariable analysis, CAUTI was not independently associated with mortality (Table 4). The primary drivers of mortality in the STS model include emergent salvage operation, second or more cardiac operation, cardiogenic shock at time of operation, increased age, and renal failure [14]. In looking at our six CAUTI patients who died, all of them had at least one of these risk factors for peri-operative mortality at the time of their operation, most commonly increased age and re-operation.

Discussion

The present study investigates significant associations between perioperative characteristics and CAUTIs within cardiac surgical patients. Not unexpectedly, the risk factors for CAUTI within this cohort of cardiac patients were similar to factors identified in other surgical and medical patient populations. For example, older age, female gender, and diabetes mellitus are all reliably associated with UTI

[4,6,15,16]. In the current analysis, age, female gender, and diabetes mellitus remained significantly correlated after controlling for confounding factors. However, emergent/urgent surgery status was no longer significantly associated.

Additionally, the strong correlation between time with Foley catheter in place and incidence of CAUTI has increased our focus on early catheter removal [4]. There has been particular emphasis because CAUTI is considered a “preventable” hospital-acquired condition by the Centers for Medicare and Medicaid Services (CMS) and therefore reimbursement is withheld if a patient acquires this condition during their hospital stay [17]. However, the argument that CAUTI is preventable with strict adherence to guidelines is debatable [18,19]. In our cohort, institution of an early Foley removal protocol in 2010 did not produce a reduction in CAUTI rate. However, this initiative coincided with more regimented screening of our cardiac surgical floor patients for CAUTI, which likely increased the number of CAUTIs captured in our database, counteracting the improvements enacted by the early catheter removal initiative.

Number of units of PRBCs transfused was significantly correlated to CAUTI on univariate analysis, which aligns with the theory that blood product transfusions lead to immunosuppression. In general, sicker patients (elevated predicted risk of mortality, cardiogenic shock, increased ICU LOS) with likely some level of immune system impairment demonstrated increased incidence of CAUTI in the present study.

The association between blood product transfusions and CAUTIs has mixed results within the literature. Ali et al. prospectively evaluated 232 consecutive cardiac patients for UTI and blood product usage [20]. They found no association between transfusions and incidence of UTI. In contrast, Rogers et al. performed a retrospective review of 24,789 Medicare beneficiaries undergoing coronary artery bypass grafting and found a significant correlation between blood product usage and UTI [7].

Among our patients with CAUTIs, there were three patients (5.5%) who also experienced DSWIs. However, the pathogens for the DSWIs and the CAUTIs were all different, with the DSWIs being bacterial in nature and the CAUTIs fungal in origin. Additionally, the DSWIs all preceded the CAUTIs. Therefore, the CAUTIs indicate global dysfunction of the immune system rather than an infection that develops to bacteremia and then translocates into the urinary tract. Additionally, the antibiotics given to combat the DSWI likely contributed to the predisposition to fungal CAUTI.

A significant association between CAUTI and 30-d mortality was found on univariate analysis. However, this relation was not maintained after controlling for confounding factors via multivariable regression. Laupland et al. demonstrated a similar relation in ICU patients, finding UTI to be correlated with mortality on univariate but not multivariable analysis [16]. Therefore, UTI appears to be a marker for sick patients with an increased likelihood of dying, but is not the causative event leading to their death.

The present findings have noteworthy clinical implications. Hospital-acquired CAUTIs are associated with significant hospital costs and patient morbidity. Measures to reduce these infections are of great importance, particularly with the current practice of refusal of reimbursement in patients with this diagnosis. The risk factors described could be used to

identify patients at high risk for CAUTI. After identification, more aggressive measures could be employed to prevent infection in these patients, including diligent early removal of Foley catheters or even prophylactic antibiotics with Foley insertion. Further studies would be needed to determine if these measures would reduce CAUTI rates or be cost-effective.

Additionally, the correlation between CAUTI and mortality on univariate but not multivariable analysis suggests that CAUTI should be viewed as a marker for a patient at increased risk for death who deserves increased diligence in clinical monitoring. This is corroborated by the fact that CAUTI patients have a greater PROM (5.0% vs. 1.8%) according to the standard risk calculator used by the Society of Thoracic Surgeons [12]. Efforts to reduce CAUTI rates are worthwhile for the reasons mentioned above, but will be unlikely to independently reduce mortality in cardiac patients.

There are select limitations within the current data. First, it is a single-center, retrospective study and has the inherent limitations associated with this study design, including possible ascertainment bias. The information on CAUTI incidence was obtained from the data tracked and maintained by our institution’s Quality Department, but this database may not consistently capture all CAUTIs. The CAUTI rate of the present study was 1.1%, which subjectively seems low to the authors based on clinical experience at our institution. CAUTI rates in cardiac surgical patients have been reported to be between 0.6% and 9.5% in the literature [4,7,10,11,16,21], with the rate reported in the present study on the low end of this spectrum.

Second, the multivariable regression only utilized five covariates because of the relatively small number of patients with CAUTIs (55) in this cohort. A larger multivariable analysis controlling for more potential confounders would provide a more thorough assessment of the factors potentially affecting CAUTI rates. Additionally, length of time with Foley in place was not included in our multivariable regression because of the low number of CAUTI patients (18) in which this time was documented. Including this value in the regression would have dramatically reduced its power. Therefore, an analysis of independently associated risk factors may produce different results if able to control for the confounding effects of variation in Foley catheter time.

In conclusion, there are several identifiable risk factors for CAUTI in cardiac surgical patients, including age, female gender, diabetes mellitus, and increased ICU LOS. Recognizing patients at high risk for CAUTI may lead to improved measures to decrease CAUTI rates within this population. Additionally, CAUTI is not independently associated with increased mortality, but it does serve as a marker of sicker patients more likely to die from other comorbidities or complications. Therefore, awareness of the high-risk nature of these patients should lead to increased diligence and may help to improve perioperative outcomes.

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Address correspondence to:

Dr. Robert G. Sawyer

Department of Surgery

University of Virginia Health System

PO Box 800709

Charlottesville, VA 22908-0709

E-mail: rws2k@virginia.edu