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Healthcare-associated infections in the postoperative period after cardiac surgery

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Abstract

This study aimed to determine the incidence of healthcare-associated infections (HAIs) in patients undergoing cardiac surgery, analyzing data and clinical outcomes in patients with and without HAIs.

This was a prospective cohort study involving 293 consecutive adult patients undergoing cardiac surgery between April 2011 and October 2012. Of the 293 patients, 60 (24.9%) developed 73 HAIs: 24 surgical site infections, 24 pneumonias, 14 urinary tract infections (UTIs), and 11 bloodstream infections (BSIs). The incidence of ventilator-associated pneumonia was 14.6 cases/1,000 ventilator-days, whereas that of catheter-associated UTI was 7.15 cases/1,000 catheter-days and that of central line-associated BSI was 4.52 cases/1,000 central line-days. Of the 60 patients with HAIs, 20 (33%) died before postoperative day 90, compared with 18 (7.7%) of the 233 patients without HAIs ($P < .001$). Independent variables associated with infection were length of hospital stay (OR 1.04; 95% C, 1.01-1.06; $P = 0.002$), duration of urinary catheter use (OR 1.19; 95% CI 1.07-1.13; $P = 0.001$), and duration of central line use (OR 1.07; 95% CI 1.01-1.13; $P = 0.032$). Independent variables associated with mortality were Acute Physiology and Chronic Health Evaluation II score (OR 1.27; 95% CI 1.14-1.42; $P < 0.001$), pneumonia (OR 11.94; 95% CI 3.83-37.17; $P < 0.001$), UTI (OR 8.59; 95% CI 1.91-38.7; $P = 0.005$), and BSI (OR 6.16; 95% CI 1.08-34.98; $P = 0.040$).

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HAIs are amongst the most important complications after cardiac surgery. Patients who experience postoperative infections have increased length of hospital stay and mortality.

Keywords: healthcare associated infections, cardiac surgery, surgical site infection, central line-associated bloodstream infection, ventilator- associated pneumonia, Brazil

Introduction

Cardiac surgery is a highly complex procedure that leaves the patient in a critical state during the postoperative period. The most common postoperative complications are cardiac-related, such as low cardiac output syndrome and acute myocardial infarction. In addition, pulmonary, neurologic, and renal complications may arise, as well as infectious diseases.[1]

A multicenter study conducted in 13 European countries in a single day showed the prevalence of infection after cardiac surgery to be 26.8%.[2] In Brazil, the reported incidence of such infection ranges from 17% to 26%.[3,4] Conterno *et al*.[3] reported the incidence of surgical site infection (SSI) to be 6.0%, compared with 2.8% for urinary tract infection (UTI), 2.5% for ventilator-associated pneumonia (VAP), 1.9% for tracheobronchitis, 1.7% for primary bloodstream infection (BSI), and 0.8% for vascular catheter-related infection. Such infections contribute to high morbidity and mortality, increasing the length and costs of hospital stays.

The objective of this study was to determine the incidence of the main healthcare-associated infections (HAIs)—pneumonia, SSI, primary BSI, and UTI—in patients undergoing cardiac surgery, analyzing the data related to and clinical outcomes of patients with and without such infections.

Methods

We prospectively followed consecutive adult patients (≥ 18 years of age) undergoing cardiac surgery at the university hospital of the Federal University of São Paulo, Brazil, between April 2011 and October 2012. The patients were followed until the end of their hospital stay (discharge or death). In the case of readmission within the first 90 days after surgery, we reinitiated the follow-up. Patients who died within the first 48 h after surgery were excluded, as were those who had any type of infection in the preoperative period and those who underwent open sternotomy with delayed sternal closure.

We collected data related to the following variables: age, sex, length of hospital stay (total duration of hospitalization, including pre and postoperative period), length of stay in the intensive care unit (ICU) (total duration in ICU, including pre and postoperative period), duration of preoperative hospitalization, in-hospital mortality, rehospitalization, diabetes mellitus, Charlson comorbidity index at ICU admission, Acute Physiology and Chronic Health Evaluation (APACHE) II score at ICU admission, American Society of Anesthesiologists (ASA) physical status classification, type of surgery, operative time (from the opening to the closing of the skin), reoperation, time on mechanical ventilation, duration of central line use, duration of urinary catheter use, presence / number of infections, type of infection, and etiologic agent.

The data were stratified by whether or not the patients developed an HAI, as well as by whether or not they evolved to death. The study was approved by the Research Ethics Committee of the Federal University of São Paulo (Protocol no. 97830). All participating patients gave written informed consent.

Routine surgical antibiotic prophylaxis was performed with 1.5 g of intravenous cefuroxime during anesthetic induction, followed by 750 mg every 4 h intraoperatively and every 8 h postoperatively, until 48 h after the procedure. In 2012, vancomycin was administered in cases of reoperation or preoperative hospitalization greater than 4 days, at a dose of 15 mg/kg, intravenously, 2 h prior to surgery and every 12 h until 48 h after the procedure. In the preoperative period, patients were bathed with 2% chlorhexidine detergent and underwent hair removal with an electric trimmer.

Pneumonia, BSI, and UTI were diagnosed in accordance with the criteria established in 2012 by the Centers for Disease Control and Prevention/ National Healthcare Safety Network (CDC/NHSN),[5-7] whereas the diagnosis of SSI was based on the 2013 CDC/NHSN criteria.[8] Therefore, SSIs were classified as superficial incisional, deep incisional, or organ/space infections, the surveillance occurring within the first 90 days after surgery.

All statistical analyses were performed with the SPSS Statistics software package, version 20.0 (IBM Corporation, Armonk, NY). Categorical variables were analyzed by chi-square test or Fisher's exact test. The differences between the two groups, in terms of the mean values, were analyzed by Student's *t*-test. To evaluate the simultaneous effect of the explanatory variables on the occurrence of infection, we used a multivariate logistic regression model. The variables included in the model were eliminated one by one in order of significance (backward method). The level of statistical significance was set at 5%.

Results

We evaluated 293 consecutive patients, 60 of which (20.5%) developed a total of 73 HAIs. Of those 73 HAIs, 24 (32.9%) were SSIs, 24 (32.9%) were pneumonias, 14 (19.2%) were UTIs, and 11 (15.1%) were BSIs. From the 60 patients with HAIs, 50 had only one infection, seven had two infections, and three had three infections. Table I shows the incidence of each type of infection, together with the incidence of infections associated with invasive devices: mechanical ventilators, urinary catheters, and central lines.

The SSIs classified as organ or space infections were mediastinitis (n = 13), 2 endocarditis (n = 2), and prosthetic valve ring abscess (n = 1). The incidence of mediastinitis was 4.4% (occurring in 13 of the 293 patients).

The demographic, clinical, and surgical characteristics of the patients with and without HAIs are shown in Table II. The two groups were similar in terms of the mean and median ages of the patients. The mean length of the hospital stay was 20 days in the no-infection group and 49 days in the infection group, a difference that was statistically significant. There were also significant differences between the two groups in terms of the length of the ICU stay, the duration of the use of invasive devices, the APACHE II score, the ASA classification, and the surgical time. Neither the Charlson comorbidity index nor the type of surgery differed statistically between the two groups. It should be noted that only the initial surgery was classified. There were statistically significant differences between the two groups in terms of the rates of reoperation and of death within the first 90 days after surgery. The mortality rate was 33.3% among the patients with infection, compared with only 7.7% among those without. A total of 47 patients underwent a second operation, which was due to SSI in 16.

The demographic, clinical, and surgical characteristics of the patients who did and did not evolve to death within the first 90 days after surgery are shown in Table III. The mean and median ages were 5 years higher among the patients who evolved to death than among those who did not. There were statistically significant differences between the patients who did and did not evolve to death, in terms of the length of the hospital stay, length of the ICU stay, duration of the use of invasive devices, APACHE II score, ASA classification, and Charlson comorbidity index. Pneumonia, BSI, and UTI were statistically significantly more common in the patients who evolved to death, as were coronary artery bypass grafting (CABG), aortic dissection surgery, and reoperation.

To evaluate the simultaneous effect that the variables shown in Table II had on the occurrence of infection, we used a multivariate logistic regression model. Initially, the variables that were significant at a level of 20% were included in the model, the only exceptions being reoperation and death, because they could be a consequence of infection. Therefore, the following variables were included in the model: diabetes mellitus; the Charlson comorbidity index; the APACHE II score; the ASA classification; the length of the hospital stay and of the ICU stay; the duration of the use of the urinary catheter, mechanical ventilator, and central line; and the surgical time. The variables were eliminated by order of significance (backward elimination). After that process, three independent variables, or predictors of infection, remained, as shown in Table IV.

Table I. Incidence of infection in patients undergoing cardiac surgery

Type of infection	HAIs (n = 73))	HAI incidence (n = 293	Cases/1,000 device-days)
Surgical site infection, n	24	8.2	-
Superficial incisional	4	1.4	-
Deep incisional	4	1.4	-
Organ/space	16	5.4	-
Pneumonia	24	8.2	-
VAP	11	-	14.6
UTI	14	4.8	-
Catheter-associated UTI	10	-	7.15
Primary BSI	11	3.8	-
Central line-associated BSI	10	-	4.52

BSI = bloodstream infection; HAI = healthcare-associated infection; UTI = urinary tract infection; VAP = ventilator-associated pneumonia.

Table II. Characteristics of patients with and without infection

Characteristic	With HAI (n=60)	Without HAI (n=233)	*P*
Age (years)			
Mean ± SD	60.33 ± 15.09	59.5 ± 15.58	0.711
Median (range)	62.5 (21-94)	61 (18-89)	
Male, n (%)	36 (60)	141 (60.5)	0.942
Length of hospital stay (days)			
Mean ± SD	49.73 ± 37.97	20.35 ± 12.87	< 0.001
Median (range)	40.5 (6-257)	17 (4-72)	
Length of ICU stay (days)			
Mean ± SD	16.88 ± 16.79	4.76 ± 3.98	< 0.001
Median (range)	11 (2-83)	4 (1-35)	
Preoperative period (days)			
Mean ± SD	11.22 ± 12.45	9.5 ± 9.73	0.253
Median (range)	7.5 (0-68)	7 (0-54)	
Diabetes mellitus, n (%)	19 (31.7)	52 (22.3)	0.132

Charlson index			
Mean ± SD	3.82 ± 2.05	3.35 ± 1.77	0.077
Median (range)	4 (1-9)	3 (0-8)	
APACHE II score			
Mean ± SD	13.22 ± 4.05	11.02 ± 4.51	< 0.001
Median (range)	13 (6-25)	11 (3-35)	
ASA physical status classification			
Mean ± SD	3.28 ± 0.58	3.08 ± 0.57	0.013
Median (range)	3 (2-5)	3 (2-5)	
Urinary catheter use (days)			
Mean ± SD	12.85 ± 14.43	3.3 ± 2.45	< 0.001
Median (range)	9.5 (2-92)	3 (1-20)	
Ventilator use (days)			
Mean ± SD	9.90 ± 14.3	1.35 ± 1.62	< 0.001
Median (range)	2.5 (1-59)	1 (0-21)	
Central line use (days)			
Mean ± SD	22.22 ± 22.51	4.78 ± 4.27	< 0.001
Median (range)	15 (2-121)	4 (0-48)	
Type of surgery			
CABG, n (%)	20 (33.3)	90 (38.6)	0.450
Valve surgery, n (%)	16 (26.7)	78 (33.5)	0.314
Aortic dissection, n (%)	11 (18.3)	32 (13.7)	0.369
CABG and other, n (%)	5 (8.3)	14 (6.0)	0.516
Other[1], n (%)	8 (13.3)	19 (8.2)	0.216
Surgical time (min)			
Mean ± SD	318.3 ± 130	273 ± 100	0.004
Median (range)	307.5 (105-840)	285 (30-600)	
Reoperation within 90 days, n (%)	26 (43.3)	21 (9)	< 0.001
Death within 90 days, n (%)	20 (33.3)	18 (7.7)	< 0.001

APACHE II = Acute Physiology and Chronic Health Evaluation II; ASA = American Society of Anesthesiologists; CABG = coronary artery bypass grafting; HAI = healthcare-associated infection; ICU = intensive care unit; 1 = pulmonary endarterectomy, carotid endarterectomy, Glenn surgery, Fontan surgery and others.

Table III. Characteristics of patients who did and did not evolve to death

Characteristics	Nonsurvival (n=38)	Survival (n=255)	*P*
Age (years)			
Mean ± SD	64.89 ± 14.51	58.89 ± 15.47	0.025
Median (range)	65.5 (24-94)	60 (18-89)	
Male, n (%)	27 (71.1)	150 (58.8)	0.150
Length of hospital stay (days)			
Mean ± SD	35.13 ± 27.85	25.06 ± 22.85	0.039
Median (range)	24.5 (4-95)	19 (5-257)	
Length of ICU stay (days)			
Mean ± SD	16.32 ± 15.39	5.89 ± 7.67	< 0.001
Median (range)	10.5 (1-67)	4 (1-83)	
Preoperative period (days)			
Mean ± SD	9.39 ± 8.32	9.92 ± 10.63	0.770
Median (range)	8 (0-54)	7 (0-68)	
Diabetes mellitus, n (%)	8 (21.1)	63 (24.7)	0.624
Charlson Index			
Mean ± SD	4.26 ± 2.12	3.32 ± 1.76	0.003
Median (range)	4.5 (1-9)	3 (1-8)	
APACHE II Score			
Mean ± SD	15.9 ± 5.84	10.84 ± 3.89	< 0.001
Median (range)	16 (7-35)	10.5 (3-23)	
ASA physical status classification			
Mean ± SD	3.37 ± 0.68	3.08 ± 0.55	0.016
Median (range)	3 (2-5)	3 (2-5)	
Urinary catheter use (days)			
Mean ± SD	11.26 ± 11.79	4.36 ± 6.82	0.001
Median (range)	6 (2-62)	3 (1-92)	
Ventilator use (days)			
Mean ± SD	11.68 ± 14.84	1.81 ± 4.33	< 0.001
Median (range)	4.5 (1-59)	1 (0-40)	
Central line use (days)			
Mean ± SD	20.5 ± 20.89	6.55 ± 10.13	< 0.001
Median (range)	12 (2-85)	4 (0-121)	
Surgical site infection, n (%)	1 (2.6)	23 (9)	0.336
Pneumonia, n (%)	15 (39.5)	8 (3.1)	< 0.001
Bloodstream infection, n (%)	6 (15.7)	5 (2.0)	0.001

Urinary tract infection, n (%)	7 (18.42)	7 (2.8)	0.001
Type of surgery			
CABG, n (%)	5 (13.2)	105 (41.2)	0.001
Valve surgery, n (%)	15 (39.5)	79 (30.9)	0.295
Aortic dissection, n (%)	13 (34.2)	30 (11.8)	< 0.001
CABG and other, n (%)	1 (2.6)	18 (7.1)	0.485
Other[1], n (%)	4 (10.5)	23 (9.0)	0.764
Surgical time (min)			
Mean ± SD	277.37 ± 159.27	283.08 ± 98.36	0.835
Median (range)	290 (30-840)	285 (75-600)	
Reoperation within 90 days, n (%)	11 (28.9)	36 (14.1)	0.020

APACHE II = Acute Physiology and Chronic Health Evaluation II; ASA = American Society of Anesthesiologists; CABG = coronary artery bypass grafting; ICU = intensive care unit; 1 = pulmonary endarterectomy, carotid endarterectomy, Glenn surgery, Fontan surgery and others.

We found that the infection risk increased 4% per day of hospital stay, 19% per day of urinary catheter use, and 7% per day of central line use, considering that the risk was constant overtime.

To evaluate the simultaneous effect that the variables shown in Table III had on mortality, we used a multivariate logistic regression model. The variables that were significant at a level of 20% were included in the model, the only exception being the length of the hospital stay, due to its multicollinearity with the other duration variables. For mortality, five independent variables remained in the model (Table V).

We found that the mortality risk was 11 times higher in the patients with pneumonia, eight times higher in those with UTI, and six times higher in those with BSI. We also found that the patients undergoing CABG were 73% less likely to die than were those undergoing other types of cardiac surgery.

The etiologic agent was identified in 45 (61.6%) of the 73 infections: *Staphylococcus aureus* in 12.3%; *Klebsiella pneumoniae* in 8.2%; *Enterobacter* spp. in 8.2%; *Pseudomonas aeruginosa* in 6.8%; *Candida* spp. in 5.5%; and others in 20.6%. Among the 13 cases of mediastinitis, five were caused by *S. aureus*, two were caused by coagulase-negative *Staphylococcus* spp., one was caused by *Enterococcus* spp., one was caused by *Acinetobacter baumannii*, and the etiologic agent was unidentified in four.

Discussion

Patients undergoing cardiac surgery are at an increased risk of infection because they are typically of advanced age and undergo multiple invasive procedures, as well as having surgical wounds in the chest and lower limbs.[9,10] In addition, many risk factors for coronary heart disease, such as diabetes mellitus, obesity, and smoking, are also risk factors for infection, and patients undergoing cardiac surgery remain in the ICU for a variable length of time.[3]

The diagnosis of infection is often difficult because inflammatory clinical and laboratory signs can be elicited by the systemic inflammatory response syndrome associated with cardiopulmonary bypass. In the present study, we evaluated 293 patients undergoing cardiac surgery. We found that the overall rate of infection was 24.9% and that the rate of SSI was 8.2%. A study conducted between 2005 and 2010 in 30 developing countries, including Brazil, by the International Nosocomial Infection Control Consortium (INICC) found that the mean rate of SSI after cardiac surgery was 5.6%.[11] That rate was significantly higher than the 1.3% reported in a CDC/NHSN study conducted in the United States (RR 4.32; 95% CI 3.81-4.88; P = 0.0001).[11] Assis *et*

Table IV. Logistic regression analysis of variables associated with infection

Variable	OR	95% CI	*P*
Hospital stay	1.04	1.01–1.06	0.002
Urinary catheter use	1.19	1.07–1.32	0.001
Central line use	1.07	1.01–1.13	0.032

Table V. Logistic regression analysis of variables associated with mortality

Variable	OR	95% CI	*P*
APACHE II Score	1.27	1.14–1.42	< 0.001
Pneumonia	11.94	3.83–37.17	< 0.001
Urinary tract infection	8.59	1.91–38.7	0.005
Bloodstream infection	6.16	1.08–34.98	0.040
CABG	.272	.080–.928	0.038

APACHE II = Acute Physiology and Chronic Health Evaluation II; CABG = coronary artery bypass grafting.

al.,[12] who used data related to 11,854 myocardial revascularization procedures, collected in 2012 by the São Paulo State Epidemiological Surveillance System, showed that the mean rate of SSI in the state, for that year, was 6.9%.[12] However, the rates reported in the studies conducted by the INICC, CDC/NHSN, and Assis *et al*.[11,12] were not separated by the type of SSI (superficial incisional, deep incisional, organ and space). Obviously, mediastinitis is the most severe type of infection. In the present study, the incidence of mediastinitis was 4.4%. Magedanz *et al*.[13] evaluated 2,809 myocardial revascularization procedures and found a rate of mediastinitis of 3.3%, which was within the 0.4-5.0% range reported in the literature.

In the present study, although we did not evaluate the incidence of SSI after hospital discharge, our patients were followed by surgeons in the outpatient clinic. The patients who required wound care, antibiotic therapy, or reoperation were readmitted and again followed, surveillance for such infection being included.

In the present study, the rate of VAP was 14.6 cases/1,000 ventilator-days. Another INICC study, conducted from 2007 to 2012 in 43 developing countries, including Brazil, reported a mean VAP rate of 10.7 cases/1,000 ventilator-days in cardiothoracic surgery ICUs.[14] That rate was significantly higher than the rate reported by the CDC/NHSN.[14] According to the São Paulo State Epidemiological Surveillance System, the median rate of VAP in general adult ICUs,was 13.3 cases/1,000 ventilator-days in 2012.[12]

In the present study, the rate of catheter-associated UTI was 7.15 cases/1,000 catheter-days, compared with a median of 5.05 cases/1,000 catheter-days in 2012 according to the São Paulo State Epidemiological Surveillance System.[12] In our sample, the rate of central line-associated primary BSI was 4.52 cases/1,000 central line-days, compared with the median of 4.42 cases/1,000 central line-days recorded for 2012 in the São Paulo State Epidemiological Surveillance System.[12] In our multivariate analysis, the length of the hospital stay, the duration of urinary catheter use, and the duration of central line use were identified as independent risk factors for infection, whereas a high APACHE II score, pneumonia, UTI, and BSI were identified as independent risk factors for mortality. Similar results are found throughout the literature. Kollef *et al*.[10] also identified the duration of urinary catheter use as one of the risk factors for infection after cardiac surgery. The risk factors for mortality were a high APACHE II score (OR 1.1; 95% CI 1.1-1.2; P = 0.019), multiple organ dysfunction (OR 23.8; 95% CI 13.5-42.1; P < 0.001), and the duration of aortic clamping. Pneumonia was independently associated with multiple organ dysfunction (OR 5.2; 95% CI 3.1-8.8; P < 0.001). Although not identified as a risk factor for infection in the multivariate analysis, the length of hospital stay was significantly longer in the patients with infection than in those without (21.0 ± 13.7 days vs. 9.7 ± 4.7 days; P < 0.001).

The longer hospital stays observed in the present study are attributable to the medical and social system, because patients treated at public hospitals have prolonged waits for diagnostic tests and surgery.

Conterno *et al*.[3] showed that the use of a urinary catheter for three days or more is a risk factor for nonsurgical infections. The authors found that pneumonia and BSI were risk factors for mortality, although, as in the present study, SSI was not. Ledur *et al*.[15] found that prolonged central line use was one of the predictors of postoperative infection after surgical myocardial revascularization (OR 1.02; 95% CI 1.00-1.02; P < 0.001).

In the present study, the mortality risk was found to be higher among the patients with infection than among those without: 11 times higher among those with pneumonia; eight times higher among those with UTI; and six times higher among those with BSI. Hortal *et al*.[16] showed that mortality was significantly higher in patients with VAP than in those without (35.0% versus 2.3%; P < 0.001). In the present study, comparing patients with VAP and other types of pneumonia, we obtained a similar result regarding the mortality rates (39.5% versus 3.1%; P < 0.001).

We have utilized this information to drive improvements in patient care and outcomes, reviewing VAP avoidance practices as well as implementing policies to limit the use of urinary catheters and central lines.

Our study has certain limitations. Because this was a single-center, observational cohort study, we cannot rule out the influence of confounding factors, which can skew the results, despite adjustment of the logistic regression model.

Healthcare-associated infections, which are common in the postoperative period after cardiac surgery, increase morbidity and mortality, consequently increasing hospital costs. Therefore, all prevention and control measures should be taken.

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