Hospitalization before surgery increases risk for postoperative infections

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Objectives: Exposure to a health care facility before surgery may increase risk for postoperative infections. Our objectives were to (1) determine whether the prevalence of postoperative infections was higher among patients who were hospitalized before cardiac surgery, (2) identify risk factors for infection, and (3) evaluate in-hospital outcomes.

Methods: A total of 32,707 patients underwent cardiac surgery from January 1, 2000, to January 1, 2011. Forty percent (13,107) were hospitalized before their surgery date or were transfers from other health care facilities, and 60% (19,600) were same-day admissions. The primary outcome consisted of a composite infection: pneumonia, sepsis, surgical site infection, and urinary tract infection. The secondary outcome was in-hospital death. The propensity method was used to compare infectious complications and mortality between groups.

Results: Overall infectious complications occurred in 2327 patients (7.1%). Overall composite and individual infections decreased over the study period (P for trend $<.0001$). Among 7814 propensity-matched pairs, 522 infections (6.7%) occurred in the same-day admission group versus 676 (8.7%) in the prior hospitalization group, $P < .0001$. In-hospital mortality was 1.5% ($n = 120$) for the same-day admission group versus 2.8% ($n = 221$) for the prior hospitalization group ($P < .0001$).

Conclusions: Although the risk of infection decreased over time, the relationship between exposure to a health care facility before surgical intervention and higher infection risk remained substantial. Further investigation into processes of care surrounding infection control is necessary to reduce postoperative infections and associated morbidity. (J Thorac Cardiovasc Surg 2014;148:1615-21)

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Postoperative nosocomial infections are among the most common noncardiac complications, with an estimated prevalence of 2.7% to 21.7%.¹⁻³ Although several patient-specific factors are reported to be associated with infection

risk, evidence suggests that exposure to a health care facility before surgery increases infectious complications postoperatively.⁴⁻⁷ Patients who acquire infections postoperatively have higher morbidity and mortality, and use of hospital resources is increased.^{1,3,4,8} Because patients cannot be randomized to hospitalization before surgery, this investigation is considered a natural experiment.⁹ To propose methods of ameliorating infection risk in cardiac surgery, the objectives of this study were to (1) determine whether the occurrence of postoperative infections was higher among patients who were hospitalized before surgery, (2) identify risk factors for infection, and (3) evaluate in-hospital mortality after infection.

PATIENTS AND METHODS

Patients

From January 1, 2000, to January 1, 2011, 32,707 adult patients underwent isolated coronary artery bypass grafting (CABG), an isolated valve procedure, combined CABG and valve surgery (with or without addition of a maze procedure or atrial septal defect repair), or ascending aorta replacement at Cleveland Clinic. A total of 13,107 patients (40%) were hospitalized before the surgery date or were transferred from other health care facilities; 19,600 (60%) presented for surgery on the day of operation. Patients who underwent heart or lung transplantation, major left ventricular procedures, endarterectomies,

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Abbreviations and Acronyms

CABG = coronary artery bypass grafting
SD = standard deviation

septal myectomies, or other procedures were excluded from this investigation. Perioperative variables were retrieved from the Cardiovascular Information Registry, a prospective database approved for use in research by the Institutional Review Board, with individual patient consent waived.

End Points

Our primary end point was a composite of postoperative infectious complications: surgical incision site infections (sternal wound, thoracotomy incision, leg and arm harvest site), septicemia, pneumonia, and urinary tract infections. A secondary end point was all-cause mortality evaluated with respect to prior hospitalization status.

Statistical Analyses

Categorical data are summarized by frequencies and percentages and continuous data by mean $\pm$ standard deviation (SD), or 15th, 50th (median), and 85th percentiles (equivalent to ± 1 SD) when the distribution was skewed. Comparisons were made using the χ^2 test, Fisher's exact test, or the Wilcoxon rank-sum test where appropriate. Uncertainty is expressed by confidence limits equivalent to ± 1 standard error (68%).

Propensity-Matched Comparison

The characteristics of the patients with prior hospitalization differed substantially from those of patients admitted on the day of surgery (Table 1). Therefore, the propensity-score method was used to obtain 2 cohorts of comparable patients for comparison of hospital outcomes.¹⁰⁻¹² Multivariable logistic regression analysis was used to identify the patient characteristics most associated with prior hospitalization (parsimonious model). The variables considered in this analysis are listed in Appendix E1. Variable selection, with a *P*-value criterion for retention of variables in the model of .05, used bagging (bootstrap aggregation),^{13,14} with automated analysis of 500 resampled data sets, followed by tabulation of the frequency of occurrence of both single factors and closely related clusters of factors. Factors with occurrence of 50% or greater were retained in the final model. Thereafter, the parsimonious model was augmented with other variables representing patient demography, symptoms, cardiac and noncardiac comorbidities, and procedure variables (semisaturated propensity model). From this, a propensity score was calculated for each patient by solving the saturated model for the probability of being in the prior hospitalization group.

Using only the propensity score, previously hospitalized patients were matched to same-day surgery patients using a greedy matching strategy.¹⁵ Patients whose propensity scores deviated more than 0.15 were considered unmatched. Greedy matching based on propensity scores yielded 7814 well-matched pairs (Figures 1 and 2 and Table 1).

Risk Factors for Infectious Complications

The occurrence of infection, time to infection, and temporal trends in the occurrence of postoperative infections were assessed. Multivariable logistic regression was performed to identify factors associated with postoperative infectious complications using the variables listed in Appendix E1 and bagging as described in the previous section.

All analyses were performed using SAS statistical software version 9.2 (SAS, Inc, Cary, NC).

RESULTS

Postoperative Infections

Prevalence. There were 2327 postoperative infectious complications overall (7.1%) among the 32,707 patients. Among the 7814 propensity-matched pairs, 676 (8.7%) experienced composite infection in the prior hospitalization group versus 522 (6.7%) in the same-day admission group, *P* < .0001. The difference was largely related to a higher prevalence of septicemia, pneumonia, and urinary tract infections in the prior hospitalization group (Table 2).

Prevalence among unmatched patients. Unmatched patients who were hospitalized before surgery had more comorbidities and a more unstable clinical presentation compared with unmatched same-day admission patients. These unmatched patients with prior hospitalizations had a higher prevalence of postoperative infections, 14% compared with 3.2% for unmatched same-day admission patients, *P* < .0001 (Table E1).

Timing. Among matched patients already hospitalized at the time of surgery, the median time from surgery to postoperative infection was 7.6 days (15th and 85th percentiles, 2.6 and 16 days, respectively; range, 0-74 days). Among matched patients admitted on the same day, the respective duration was 7.5 days (15th and 85th percentiles, 2.7 and 15 days, respectively; range, 0-53 days).

Temporal trends. The overall number of same-day admissions and hospital transfers remained relatively unchanged over the study period (Figure 3). A temporal trend of decreased prevalence of all types of infections was observed (*P* < .0001; Figures 4 and 5).

Risk factors. Several demographic, comorbidity, clinical presentation, and procedural factors were associated with a higher risk of composite infection (Table 3). Hospitalization before surgery was associated with a 1.9-fold increase in infection risk, greater than that of other comorbidities, including diabetes. Emergency surgery and intraoperative red blood cell transfusion were the only other variables that placed a patient at greater or similar risk of infection as prior hospitalization.

Mortality

Unadjusted in-hospital mortality was 0.85% (*n* = 167) for the same-day admission groups and 4.0% (*n* = 522) for the prior hospitalization group (*P* < .0001); for matched patients, it was 1.5% (*n* = 120) and 2.8% (*n* = 221), respectively (*P* < .0001). Mortality was lower among unmatched same-day admission patients (0.4%) than patients hospitalized before surgery (5.7%; *P* < .0001) (Table E1).

DISCUSSION

Principal Findings

Hospitalization before cardiac surgery was associated with more postoperative infectious complications than

TABLE 1. Patient and operative characteristics by same-day and prior hospital admission status: before and after propensity matching

Variable	Same-day admission					Prior admission			
	Before matching (n = 19,600)		After matching (n = 7814)		P†	After matching (n = 7814)		Before matching (n = 13,107)	
	n*	No. (%) or mean ± SD	n*	No. (%) or mean ± SD		n*	No. (%) or mean ± SD	n*	No. (%) or mean ± SD
Demographics									
Age (y)	19,600	63 ± 14	7814	66 ± 13	.10	7814	66 ± 13	13,107	66 ± 13
Female	19,600	5831 (30)	7814	2543 (33)	.3	7814	2606 (33)	13,107	4869 (37)
Race	19,464		7741			7703		12,916	
White		17,669 (91)		6860 (89)	.6		6804 (88)		11,206 (87)
Black		618 (3.2)		417 (5.4)	.3		445 (5.8)		1101 (8.5)
Other		1177 (6.0)		464 (6.0)	.8		454 (5.9)		609 (4.7)
Body surface area (m ²)	19,594	2.0 ± 0.26	7810	2.0 ± 0.27	.5	7809	2.0 ± 0.28	13,097	2.0 ± 0.28
Hospital transfer	19,600	0 (0)	7814	0 (0)	—	7771	3189 (41)	13,030	6122 (47)
Clinical presentation									
NYHA functional class	19,593		7810		.004	7812		13,102	
I		5725 (29)		1427 (18)			1426 (18)		1943 (15)
II		10,113 (52)		4037 (52)			3874 (50)		5767 (44)
III		3364 (17)		2002 (26)			2088 (27)		3925 (30)
IV		391 (2.0)		344 (4.4)			424 (5.4)		1467 (11)
Emergency surgery	19,597	78 (0.40)	7814	76 (0.97)	.0002	7814	128 (1.6)	13,107	486 (3.7)
Cardiac comorbidity									
LVEF (%)	15,857	53 ± 11	6370	49 ± 12	.6	6505	49 ± 12	10,866	47 ± 13
Myocardial infarction	19,600	4476 (23)	7814	3006 (38)	.3	7814	3072 (39)	13,107	6117 (47)
Heart failure	19,600	3271 (17)	7814	2338 (30)	.003	7813	2508 (32)	13,106	5793 (44)
Endocarditis	19,600	612 (3.1)	7814	284 (3.6)	.05	7814	331 (4.2)	13,107	997 (7.6)
Atrial fibrillation/flutter	17,395	1530 (8.8)	6794	809 (12)	.6	7534	873 (12)	12,667	1600 (13)
Prior cardiac surgery	19,600	3770 (19)	7814	2119 (27)	.2	7814	2188 (28)	13,107	3942 (30)
No. of cardiac operations	19,600		7814		.4	7814		13,107	
1		15,830 (81)		5695 (73)			5626 (72)		9165 (70)
2		3175 (16)		1688 (22)			1712 (22)		2961 (23)
≥3		595 (3.0)		431 (5.5)			476 (6.1)		981 (7.5)
Complete heart block or pacemaker	17,395	680 (3.9)	6794	403 (5.9)	.5	7534	427 (5.7)	12,667	792 (6.3)
Ventricular arrhythmia	17,395	1602 (9.2)	6794	633 (9.3)	.6	7534	722 (9.6)	12,667	1215 (9.6)
Noncardiac comorbidity									
Carotid disease	19,600	4906 (25)	7814	3008 (38)	.6	7814	3037 (39)	13,107	5746 (44)
Hypertension	19,600	12,583 (64)	7814	6004 (77)	.8	7814	5994 (77)	13,107	10,356 (79)
Pharmacologically treated diabetes	19,444	3259 (17)	7720	2019 (26)	.5	7697	2049 (27)	12,856	3832 (30)
Insulin-treated diabetes	19,422	1142 (5.9)	7710	779 (10)	.2	7687	821 (11)	12,836	1675 (13)
PAD	19,600	1460 (7.4)	7814	996 (13)	.9	7814	1003 (13)	13,107	2007 (15)
COPD	19,600	2361 (12)	7814	1369 (18)	.5	7813	1403 (18)	13,106	2776 (21)
Smoking	19,600	9897 (51)	7760	4593 (59)	.7	7763	4574 (59)	13,018	8047 (62)
Renal dialysis	19,600	91 (0.46)	7814	75 (0.96)	.0007	7813	122 (1.6)	13,106	376 (2.9)
Stroke	19,600	1056 (5.4)	7814	746 (9.5)	.15	7814	800 (10)	13,107	1860 (14)
Creatinine (mg/dL)	19,555	1.07 ± 0.62	7795	1.16 ± 0.85	.04	7811	1.18 ± 0.84	13,099	1.29 ± 1.07
Bilirubin (g/dL)	19,496	0.68 ± 0.41	7751	0.67 ± 0.45	.02	7417	0.69 ± 0.47	12,458	0.71 ± 0.59
Glomerular filtration rate (MDRD)	19,555	78 ± 22	7795	74 ± 25	.04	7811	74 ± 26	13,099	71 ± 29
Hematocrit (%)	19,593	40 ± 5.3	7808	38 ± 5.6	.002	7814	38 ± 5.8	13,105	36 ± 6.2
Procedure									
Isolated CABG	19,600	4379 (22)	7814	2847 (36)	<.0001	7814	3127 (40)	13,107	5160 (39)
Isolated valve	19,600	8588 (4)	7814	1910 (24)	.7	7814	1932 (25)	13,107	2964 (23)
Combined CABG/valve	19,600	3472 (18)	7814	1742 (22)	<.0001	7814	1472 (19)	13,107	2752 (21)
Aortic root, ascending aorta	19,600	2615 (13)	7814	1138 (15)	.6	7814	1113 (14)	13,107	1903 (15)
Other cardiac	19,600	546 (2.8)	7814	177 (2.3)	.7	7814	170 (2.2)	13,107	328 (2.5)

(Continued)

TABLE 1. Continued

Variable	Same-day admission					Prior admission			
	Before matching		After matching		P†	After matching		Before matching	
	(n = 19,600)		(n = 7814)			(n = 7814)		(n = 13,107)	
	n*	No. (%) or mean ± SD	n*	No. (%) or mean ± SD		n*	No. (%) or mean ± SD	n*	No. (%) or mean ± SD
Surgical invasiveness	19,598		7812			7813		13,106	
Full incision		14,453 (74)		7302 (93)	.7		7289 (93)		12,493 (95)
Less invasive		4691 (24)		46 (6)	.3		43 (5.6)		503 (3.8)
Percutaneous/ports		454 (2.3)		42 (0.54)	<.0001		88 (1.1)		110 (0.84)
CPB	19,600	18,776 (96)	7814	7308 (94)	.07	7814	7250 (93)	13,107	12,123 (92)
CPB time (min)	19,600	93 ± 43	7814	99 ± 48	.008	7814	101 ± 50	13,107	106 ± 54
Myocardial ischemic time (min)	19,600	72 ± 34	7814	76 ± 37	.04	7814	77 ± 39	13,107	79 ± 41
Requirement for IABP	19,600	205 (1.0)	7814	142 (1.8)	.8	7814	146 (1.9)	13,107	387 (3.0)
Blood product use									
RBC transfusion	19,593	7347 (37)	7809	4209 (54)	<.0001	7807	4603 (59)	13,095	8920 (68)
FFP	19,591	1801 (9.2)	7807	1112 (14)	<.0001	7805	1492 (19)	13,091	3089 (24)
Any blood product	19,600	7973 (41)	7814	4472 (57)	<.0001	7814	4854 (62)	13,107	9262 (71)
Immunosuppressive therapy	19,600	2740 (14)	7814	1120 (14)	.6	7814	1142 (15)	13,107	2111 (16)
Outcome									
In-hospital death	19,600	167 (0.85)	7814	120 (1.5)	<.0001	7814	221 (2.8)	13,107	522 (4.0)

SD, Standard deviation; NYHA, New York Heart Association; LVEF, left ventricular ejection fraction; PAD, peripheral arterial disease; COPD, chronic obstructive pulmonary disease; MDRD, Modification of Diet in Renal Disease formula; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; IABP, intra-aortic balloon pump; RBC, red blood cell; FFP, fresh frozen plasma. *Patients with data available. †Matched group comparison.

same-day admission, even after accounting for commonly reported risk factors for infection in this setting. Most infections occurred beyond a week postoperatively, but at our institution, their frequency is decreasing.

Prevalence. An investigation from the 1980s reported that longer length of hospital stay before cardiac surgery

increased infectious risk postoperatively. Although the investigators noted that increased risk could reflect the severity of illness, they also believed it was partially attributable to exposure to the hospital's microorganisms.⁷ An investigation from a noncardiac surgical setting using the American College of Surgeons National Safety Quality Improvement Project found increased risk for surgical site infections, pneumonia, and urinary tract infections in patients who were hospitalized preoperatively (odds ratio, 1.21; confidence interval, 1.06-1.39). They also attributed colonization with bacteria from the health care setting and the presence of foreign catheters as potential risk factors.⁶ Other investigators have also reported on increased infectious risks associated with hospitalization before surgical procedures; however, few comment on practical preventive measures.^{5,6} Although inpatient hospitalization may be considered a surrogate for greater acuity of illness, it also remained a risk factor after propensity matching accounted for high-risk comorbid conditions, complex procedures, and emergency surgery. Occurrence of postoperative infections is related to the presence of devices (urinary catheters, central venous cannulation, and arterial line monitoring), extensive surgical incision sites, and routine need for postoperative ventilatory support.^{3,6,16}

Timing. Using the Nationwide In-patient Sample, Vogel and colleagues⁴ reported that hospitalization before CABG was associated with increased postoperative infections (pneumonia, urinary tract infections, and sepsis) in an incremental manner, with increasing days of preoperative hospitalization associated with more postoperative

FIGURE 1. Mirrored histogram of propensity scores for patients who were hospitalized before surgery and those who were same-day admissions. Shaded areas represent propensity-matched groups.

FIGURE 2. Covariance balance plot before and after propensity matching for patients in the same-day admission and prior hospitalization groups, standardized for comparability.²⁴ *LVEF*, Left ventricular ejection fraction; *Clr*, clearance; *AFib*, atrial fibrillation; *COPD*, chronic obstructive pulmonary disease; *ITA*, internal thoracic artery; *CABG*, coronary artery bypass grafting; *NYHA*, New York Heart Association.

infections: 0 days, 5.73%; 1 day, 11.86%; 2-5 days, 15.79%; and 6-10 days, 18.24%.

Temporal trends. The percentages of patient transfers to our health care facility and those admitted preoperatively were relatively unchanged over the duration of this investigation. Infectious complications decreased over time, however, and never reached zero. We attributed this trend to several institution-specific factors: movement of cardiothoracic services to a new facility, implementation of and increased compliance efforts for several quality initiatives, such as more aggressive glucose control, hand washing, efforts to reduce central line–associated bloodstream infection, and more appropriate antibiotic stewardship. One would expect that implementation of these infection control initiatives over this time period would serve to decrease the prevalence of infections similarly for both groups.

Risk factors. Our reported findings of older age, obesity, diabetes, immunosuppressive therapy, emergency surgery,

and red blood cell transfusion are similar to other reports on risk factors for postoperative infectious complications.^{1,3,16-18} Although identification of patient-specific risk factors for infection is important, many of these are unfortunately not modifiable at the time of surgical intervention.

Mortality

We found, like others, that once postoperative infections develop, they place patients at considerable risk of mortality and higher costs are incurred.⁴

Clinical Implications

Despite attempts to identify and implement initiatives to reduce postoperative infections, we are unable to eliminate them. Avoiding unnecessary preoperative admissions should be considered first, but it is difficult to determine the necessity of admission when multiple services are involved (medicine and surgery) in the care of these patients, and surgeons are often consulted days after hospitalization. Investigators have recommended research into strategies that could aid clinicians in deciding whether preoperative hospitalizations are necessary.⁶

Creating and assessing the cost, safety, and effectiveness of a new infection control strategy for hospitalized patients undergoing cardiac surgical procedures may serve to improve outcomes. For example, Huang and colleagues¹⁹ conducted a pragmatic randomized trial in adult patients in intensive care, examining targeted versus universal decolonization with daily chlorhexidine bathing to prevent infections. Universal decolonization reduced positive clinical cultures of methicillin-resistant *Staphylococcus aureus* by 37% and bloodstream infections from any pathogen by 44%. Additional benefits noted by the investigators were a reduced environmental microbial burden and decreased risk for patient-to-patient transmission. More formalized policies in our own institution have been initiated, including

TABLE 2. Postoperative infectious complications by same-day admission and hospitalization before surgery: overall and matched groups

Complication	Same-day admission			<i>P</i> *	Prior admission	
	Total	Before matching	After matching		After matching	Before matching
	(n = 32,707)	(n = 19,600)	(n = 7814)		(n = 7814)	(n = 13,107)
	No. (%)	No. (%)	No. (%)		No. (%)	No. (%)
Postoperative composite infection	2327 (7.1)	904 (4.6)	522 (6.7)	<.0001	676 (8.7)	1423 (11)
Surgical site						
Deep sternal wound	317 (0.97)	163 (0.83)	99 (1.3)	.7	93 (1.2)	154 (1.2)
Leg vein harvest site	140 (0.42)	44 (0.22)	29 (0.37)	.03	48 (0.61)	92 (0.70)
Arm vein harvest site	5 (0.02)	3 (0.015)	2 (0.025)	.6	1 (0.013)	2 (0.015)
Urinary tract infection	986 (3.0)	403 (2.1)	225 (2.5)	.02	278 (3.6)	583 (4.4)
Septicemia	970 (3.0)	318 (1.6)	185 (2.4)	<.0001	280 (2.6)	652 (5.0)
Pneumonia	706 (2.2)	219 (1.1)	134 (1.7)	.0001	203 (2.6)	487 (3.7)

*Comparison of matched groups.

FIGURE 3. Percentage of patients hospitalized before cardiac surgery (blue). Approximately 20% of these were transfers from other health care facilities (black).

preoperative daily bathing and decolonization while awaiting operation.

Limitations

We are limited by the nature of our observational cohort study design whereby variables that are unaccounted for could influence our study findings. However, we included known pre- and intraoperative risk factors for postoperative infections and used modern statistical methods for risk adjustment. Our focus was on pre- and intraoperative variables that could lead to process improvement or modifiable risk factors. Hence, we did not include postoperative complications, which are hard to predict and may have occurred after the infectious complications.

Another important limitation of our study is the lack of data on the microbiology of infective organisms. Had these data been available, potential differences in patterns of infectious organisms between hospitalized

FIGURE 4. Percentage of patients developing a composite postoperative infectious complication in-hospital over time. *Postop*, Postoperative.

FIGURE 5. Percentage of patients developing specific postoperative infections over time. *UTI*, Urinary tract infection; *Pneum*, pneumonia.

patients and same-day admissions could have been identified, potentially leading to improvements in current infection control and prevention. Gardlund and colleagues²⁰ reported that postoperative mediastinitis could be classified into groups based on microbiology and pathogenesis, for example: (1) mediastinitis associated with obesity, chronic obstructive pulmonary disease, and sternal dehiscence, typically caused by coagulase negative staphylococci; and (2) mediastinitis after perioperative contamination of the mediastinal space often caused by *S aureus*.

A significant number of prior hospitalized patients were transferred from other hospitals. Specific data on hospitalization days at outside institutions were unavailable. Therefore, we were unable to examine the relationship between preoperative length of stay and subsequent infection sequelae. Similarly, data on the presence of invasive lines, urinary catheters, and ventilator dependency were not available, so their relationship with postoperative infections could not be examined.

We were unable to determine which patients truly needed inpatient hospitalization and which could have been stabilized and sent home to return as a same-day admission. Although we suggest universal decontamination of patients transferred from another hospital and those hospitalized before surgery, we were unable to determine with certainty whether this process improvement intervention would further reduce infectious complications.

We do not consider our use of a composite end point of infectious complications to be a limitation of our work. Our composite outcome data comprise complications of a similar nature and followed similar trends over time. Certainly, the use of composite end points combining dissimilar types of data should be approached with caution, as they are associated with several limitations.²¹⁻²³

TABLE 3. Risk factors for postoperative infection (all, n = 32,707)

Risk factor	Estimate ± SE	P
Prior hospitalization	0.57 ± 0.15	.0002
Demographics		
Older age*	0.24 ± 0.043	<.0001
Female	0.22 ± 0.066	.0007
Weight‡ (heavier)	0.30 ± 0.04	<.0001
Height‡ (shorter)	−1.2 ± 0.29	<.0001
Race: nonwhite	0.15 ± 0.069	.03
Status/symptoms		
Emergency surgery	0.74 ± 0.12	<.0001
Higher NYHA class§	0.022 ± 0.0062	.0005
Immunosuppressant therapy	0.24 ± 0.057	<.0001
Comorbidities		
Myocardial infarction	0.13 ± 0.052	.01
Chronic obstructive pulmonary disease	0.35 ± 0.053	<.0001
Prior stroke	0.32 ± 0.064	<.0001
Insulin-treated diabetes	0.24 ± 0.070	.0005
Laboratory values		
BUN	0.30 ± 0.079	.0002
Hematocrit¶ (lower)	0.19 ± 0.14	.17
Prior cardiac operation#	0.068 ± 0.035	.05
Procedural		
Aorta	0.40 ± 0.071	<.0001
Mitral valve surgery	0.22 ± 0.062	.0005
Coronary artery bypass grafting	0.18 ± 0.060	.003
Mitral valve replacement	0.23 ± 0.076	.003
Aortic valve replacement	0.16 ± 0.053	.003
Tricuspid valve surgery	0.24 ± 0.074	.001
Full incision	0.22 ± 0.10	.03
Intraoperative RBCs	0.51 ± 0.057	<.0001
Surgeon A	0.29 ± 0.081	.0004
Surgeon B	0.29 ± 0.14	.03
Earlier date of operation**	−0.15 ± 0.016	<.0001
More recent operation††	0.28 ± 0.049	<.0001
Risk factors unique to prior hospitalization		
NYHA class II	−0.31 ± 0.070	<.0001
Lower LVEF	−0.0070 ± 0.0024	.004
Higher BUN	0.0070 ± 0.0026	.008
Higher bilirubin	0.19 ± 0.044	<.0001
Risk factors unique to same-day admission		
Heart failure	0.23 ± 0.081	.005
Peripheral arterial disease	0.33 ± 0.10	.002
Treated diabetes	0.22 ± 0.086	.01
Surgeon C (less risk)	−0.59 ± 0.22	.008
Intercept	−4.7 ± 0.40	<.0001

C-statistic = .76. SE, Standard error; NYHA, New York Heart Association; BUN, blood urea nitrogen; RBC, red blood cells; LVEF, left ventricular ejection fraction. *(Age/50)², squared transformation. †(Weight [kg]/80)², squared transformation. ‡(Height [cm]/180)², squared transformation. §(NYHA class)², squared transformation. ||Logarithmic transformation. ¶(40/hematocrit), inverse transformation. #Number of cardiac surgeries. **Years from 1/1/2000. ††Log transformation (years from 1/1/2000).

CONCLUSIONS

Despite the decrease in infectious complications after cardiac surgery over time, exposure to a health care facility before surgical intervention remains an important risk factor for infection and hospital mortality. When prior hospitalization is unavoidable, we empirically suggest daily

universal decontamination for hospital transfers and patients hospitalized before surgery to further reduce postoperative infections. Additional investigation would provide more definitive information on whether the suggested process improvement initiative would further reduce infections.

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APPENDIX E1. Variables considered in the analyses**Patient**

Demographics	Age (y),* weight (kg), height (cm), weight/height ratio, body surface area (m ²),* body mass index (kg/m ²),* gender,* race*
Symptoms	NYHA functional class (I-IV),* NYHA functional class (I-IV) <14 d before surgery, Canadian angina class, emergency operation
Ventricular dysfunction	Previous myocardial infarction*
Cardiac comorbidity	Atrial fibrillation,* complete heart block or pacer,* ventricular arrhythmia,* heart failure,* endocarditis,* prior cardiac surgery,* total number of cardiac operations
Noncardiac comorbidity	Peripheral arterial disease,* carotid disease,* hypertension,* pharmacologically treated diabetes,* insulin-treated diabetes, non-insulin-treated diabetes, chronic obstructive pulmonary disease,* history of smoking,* preoperative renal dialysis,* prior stroke,* creatinine (mg/dL),* blood urea nitrogen (mg/dL),* bilirubin (mg/dL),* creatinine clearance,* glomerular filtration rate (Modification of Diet in Renal Disease),* hematocrit (%),* total cholesterol (mg/dL), high-density lipoprotein (mg/dL), low-density lipoprotein (mg/dL), triglycerides (mg/dL), red blood cell and component therapy transfusion
	Date of operation (years since January 1, 2000)*
Procedure	Coronary artery bypass grafting,* aortic valve procedure,* mitral valve procedure,* tricuspid valve procedure*

NYHA, New York Heart Association. *Variables used in the propensity model.

TABLE E1. Baseline variables, perioperative factors, and mortality for unmatched patients by same-day admission and prior hospitalization status

Variable	Same-day admission (n = 11,786)		Prior hospitalization (n = 5293)		P
	n*	No. (%) or mean ± SD	n*	No. (%) or mean ± SD	
Demographics					
Age (y)	11,786	61 ± 14	5293	68 ± 12	<.0001
Female	11,786	3267 (28)	5293	2273 (43)	<.0001
Race					
White	11,723	10,809 (92)	5213	4402 (84)	<.0001
Black	11,723	201 (1.7)	5213	656 (13)	<.0001
Other	11,723	713 (6.1)	5213	155 (3.0)	<.0001
Body surface area (m ²)	11,784	2.02 ± 0.25	5288	2.0 ± 0.28	<.0001
Hospital transfer	11,786	0 (0)	5259	2933 (56)	—
Clinical presentation					
NYHA functional class	11,783		5273		<.0001
I		4298 (36)		517 (9.8)	
II		6076 (52)		1893 (36)	
III		1362 (12)		1837 (35)	
IV		47 (0.40)		1043 (20)	
Emergency surgery	11,783	2 (0.017)	5292	358 (6.8)	<.0001
Cardiac comorbidity					
LVEF (%)	9487	55 ± 8.9	4361	44 ± 14	<.0001
Myocardial infarction	11,786	1470 (12)	5293	3045 (58)	<.0001
Heart failure	11,786	933 (7.9)	5293	3285 (62)	<.0001
Endocarditis	11,786	328 (2.8)	5293	666 (13)	<.0001
Atrial fibrillation/flutter	10,601	721 (6.8)	5133	727 (14)	<.0001
Prior cardiac surgery	11,785	1651 (14)	5293	1754 (33)	<.0001
No. of cardiac operations	11,786		5293		<.0001
1		10,135 (86)		3539 (67)	
2		1487 (13)		1249 (24)	
≥3		64 (1.4)		505 (9.5)	
Complete heart block or pacer	10,601	277 (2.6)	5133	365 (7.1)	<.0001
Ventricular arrhythmia	10,601	969 (9.1)	5133	493 (9.6)	.4
Noncardiac comorbidity					
Carotid disease	11,786	1898 (16)	5293	2709 (51)	<.0001
Hypertension	11,786	6579 (56)	5293	4362 (82)	<.0001
Pharmacologically treated diabetes	11,724	1240 (11)	5159	1783 (35)	<.0001
Insulin-treated diabetes	11,690	370 (3.2)	5133	860 (17)	<.0001
Peripheral arterial disease	11,786	464 (3.9)	5293	1011 (19)	<.0001
COPD	11,786	992 (8.4)	5293	1373 (26)	<.0001
Smoking	11,720	5304 (45)	5323	3487 (67)	<.0001
Renal dialysis	11,786	16 (0.14)	5293	254 (4.8)	<.0001
Stroke	11,786	310 (2.6)	5293	1060 (20)	<.0001
Creatinine (mg/dL)	11,760	1.01 ± 0.36	5270	1.46 ± 1.32	<.0001
Bilirubin (g/dL)	11,745	0.69 ± 0.38	5041	0.74 ± 0.73	<.0001
Glomerular filtration rate (MDRD)	11,760	80 ± 20	5288	67 ± 33	<.0001
Hematocrit (%)	11,785	40 ± 4.8	5291	34 ± 6.0	<.0001
Procedure					
Isolated CABG	11,786	1532 (13)	5293	2033 (38)	<.0001
Isolated valve	11,786	6678 (57)	5293	1032 (19)	<.0001
Combined CABG/valve	11,786	1730 (15)	5293	1280 (24)	<.0001
Aortic root, ascending aorta	11,786	1477 (13)	5293	790 (15)	<.0001
Other cardiac	11,786	369 (3.1)	5293	158 (3.0)	.6
Surgical invasiveness					

(Continued)

TABLE E1. Continued

Variable	Same-day admission (n = 11,786)		Prior hospitalization (n = 5293)		P
	n*	No. (%) or mean $\pm$ SD	n*	No. (%) or mean $\pm$ SD	
Full incision	11,786	7151 (61)	5293	5204 (98)	<.0001
Less invasive	11,786	4223 (36)	5293	67 (1.3)	<.0001
Percutaneous/ports	11,786	412 (3.6)	5293	22 (0.41)	<.0001
CPB	11,786	11,468 (97)	5293	4873 (92)	<.0001
CPB time (min)	11,786	89 $\pm$ 38	5293	113 $\pm$ 58	<.0001
Myocardial ischemic time (min)	11,786	69 $\pm$ 31	5293	82 $\pm$ 45	<.0001
Requirement for IABP	11,786	63 (0.53)	5293	241 (4.6)	<.0001
Blood product use					
RBC transfusion	11,784	3138 (27)	5288	4317 (82)	<.0001
FFP	11,784	689 (5.8)	5286	1597 (30)	<.0001
Any blood product	11,786	3501 (30)	5293	4408 (83)	<.0001
Immunosuppressive therapy	11,786	1620 (14)	5293	969 (18)	<.0001
Outcome					
Postoperative infection	11,786	383 (3.2)	5293	747 (14)	<.0001
In-hospital death	11,786	47 (0.4)	5293	301 (5.7)	<.0001

SD, Standard deviation; NYHA, New York Heart Association; LVEF, left ventricular ejection fraction; COPD, chronic obstructive pulmonary disease; MDRD, Modification of Diet in Renal Disease formula; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; IABP, intra-aortic balloon pump; RBC, red blood cell; FFP, fresh frozen plasma. *Patients with data available.