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Surgical site infection after valvular or coronary artery bypass surgery: 2008–2011**French national SSI-RAISIN surveillance**

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SUMMARY

Background: Multisite information regarding surgical site infection (SSI) rates for cardiac surgery programmes is not widely available. Ward characteristics that may affect outcomes have not been analysed previously.

Aim: To determine individual- and ward-level factors associated with SSI occurrence after coronary artery bypass grafting (CABG) and valvular surgery.

Methods: A dataset from the French national database SSI-RAISIN 2008–2011 was used. Only adult patients were included. A standardized questionnaire was completed for each patient who underwent surgery, and patients with and without SSI were characterized. Patients and ward risk factors for SSI were analysed using a multilevel logistic regression model with SSI as binary outcome (two levels: patient and ward).

Results: Out of 8569 patients from 39 wards, the SSI rate was 2.2%. Micro-organisms were isolated in 144 patients (74%): 35% coagulase-negative staphylococci ($N = 51$), 23%

Staphylococcus aureus ($N = 33$), 6% *Escherichia coli* ($N = 8$). Higher probability of SSI was associated with the duration of preoperative hospitalization, the duration of follow-up, the duration of surgery >75th percentile and the SSI rate in the surgery ward. The residual heterogeneity between wards (median odds ratio: 1.53) was as relevant as duration of preoperative hospitalization (odds ratio: 1.57).

Conclusion: Although patient risk factors were more strongly associated with SSI occurrence, this study provided evidence for the existence of a ward-level effect. This should be taken into account when considering possible corrective interventions.

Keywords:

Cardiac surgery

Coronary artery bypass graft

Surgical site infection

Surveillance

Valvular surgery

Introduction

Surveillance systems (along with infection control programs) can reduce surgical site infections (SSI) rates.¹⁻³ SSI after cardiac surgery increase the patient morbidity and mortality, the length of hospital stay and hospital costs.⁴ Multisite information regarding SSI rates for cardiac surgery programmes is not readily available. Moreover, SSI risk factors after coronary artery bypass graft (CABG) and valvular surgery have rarely been assessed by population-based or multicentre studies. Previously identified risk factors, such as obesity, are generally not amenable to corrective action.⁴⁻⁷ By identifying the role of the specific risk factors related to the treating facility, such as ward characteristics, it is possible that interventions could be undertaken to reduce SSI rates.⁸ The aim of this study was to describe SSI after CABG and valvular surgery from the French national database SSI-RAISIN 2008–2011, in order to identify significant individual- and ward-level factors associated with SSI occurrence.

Methods

Population

A dataset of adult patients who underwent a valvular or CABG surgical procedure during the four-year period 2008–2011 was analysed: 8569 patients from 39 wards from 31 healthcare facilities.

Data collection

Yearly surveillance included at least three months during the annual survey period (January to June). Details of data collection and management methods for the SSI-RAISIN

system have been previously published.^{1,9} SSI diagnostic criteria used by surgical teams accorded with the standardized Centers for Disease Control definitions. This study was given ethical clearance by the French data protection authority.

A sternal wound infection included at least one of the following: (i) presence of purulent drainage; (ii) bacterial isolation from the incision; (iii) presence of at least one of the following symptoms: tenderness, swelling, redness, or heat; (iv) diagnosis made by the surgeon or physician.

A standardized data collection form was completed for each patient who underwent surgery during the surveillance periods. For cardiac surgery, the classification of the procedure was categorized as follows: closed-heart surgery, open-heart surgery, CABG with saphenous vein graft, CABG with internal thoracic arterial graft, valvular surgery, and intrathoracic arteries surgery as categorized by the French Medical Acts Classification.

The following preoperative characteristics were considered: age, sex, duration of preoperative hospitalization (<48 h vs \geq 48 h), wound class (Altemeier classification), the American Society of Anesthesiologists (ASA) physical status score, duration of surgery (\leq 75th percentiles versus >75th percentiles; the 75th percentile was 5 h for CABG with the use of internal thoracic arteries, 4 h with the use of saphenous vein and for valvular procedures), emergency versus elective surgery, ambulatory surgery, type of procedure, duration of postoperative follow-up, SSI occurrence during hospitalization or after discharge, depth of infection (superficial, deep, organ/space), average delay between the surgery and SSI diagnosis, revisions surgery, patient outcome (alive/deceased), National Nosocomial Infections Surveillance system (NNIS) risk index of the surgery (based on risk factors for infection: ASA classification >2, duration of surgery >75th percentile, and wound contamination >2).¹⁰

The following ward-based characteristics were considered: hospitalization ward, global cardiac surgery SSI rate, valvular and CABG SSI rate, the number of cardiac surgery procedures per month, the average duration of patients' follow-up after surgery, and the proportion of NNIS 0 patients.

Statistical analysis

First, a descriptive analysis of patients with and without SSI was performed with the R[®] software version 2.15.3.

Risk factors for SSI were estimated with a multilevel logistic regression model with SSI as a binary outcome.¹¹ Data structure had two levels: patients (first level) and wards (second level). An 'empty' model (model A) only included a random intercept and allowed detection of a possible contextual dimension. Thereafter, the individual characteristics were

included in the model (model B) to investigate the extent to which ward incidence differences were explained by the individual patients of the wards. Ward characteristics were included in a third model (model C). Multivariate analyses were performed by stepwise logistic regression. All variables with $P \leq 0.10$ in the univariate analysis or which were thought to be associated with SSI from the literature were included in the models. $P < 0.05$ was considered significant.^{12–15} For quantifying heterogeneity between clusters, the median odds ratio (MOR) was calculated and intraclass correlation (ICC) was estimated with the linear threshold model method.¹⁶ MLwiN[®] software 2.15 was used for univariate and multivariate analyses.

Cost assessment

The cost assessment adopted the healthcare payer's perspective, the healthcare insurance, and took into account only hospitalization costs. Hospitalization costs (such as nursing, medical care, pharmacy, diagnostic tests, staff, general equipment, administration, security, central supply, dietetics or social services) were assessed using the French diagnosis-related groups that fund all costs.^{17,18} The average additional cost of valvular or coronary artery bypass surgery with a deep SSI compared to the same support without SSI was estimated from the database of the University Hospital of Toulouse (€11,000). The total additional cost was calculated by multiplying the total number of deep SSIs by the estimated average incremental cost. Costs were expressed in euros.

Results

The SSI rate was 2.5% in 2008 (52/2071), 1.9% in 2009 (35/1815), 2.2% in 2010 (45/2075), and 2.3% in 2011 (62/2698) with no significant difference between years ($P = 0.60$).

Ward characteristics

Only five wards participated in the surveillance every year. The number of valvular and CABG surgeries per month ranged from 11 to 111 [median: 44; interquartile range (IQR): 26–77]. The proportion of NNIS-0 patients on the various wards ranged from 0 to 80% (median: 2.5%; IQR: 1–6%).

Six healthcare facilities had two different surgery wards performing cardiac surgery and one had three different wards: as there were substantial differences in SSIs between wards in the same healthcare facility, these wards were considered separately.

Ward SSI rates ranged from 0% to 5% (median: 1.7%; IQR: 0.7–2.9; cf. Figure 1). At ward level, the mean duration of patient's follow-up was 32 days (mean: 30; IQR: 9–41).

Patient characteristics

Out of 8659 CABG or valvular procedures, the overall SSI rate was 2.2%. Patient characteristics are recorded in Table I: 61% of SSIs were diagnosed during hospitalization,

45% were superficial SSIs and 48% deep or organ space (sternitis, mediastinitis, and endocarditis) SSI. Depth of infection was not specified for 12 patients (6%).

Average (\pm SD) time from surgery to SSI onset was 14 days (\pm 7.14) without significant difference being noted between CABG and valvular surgery. The mean duration of hospital stay after surgery was 23 days in SSI patients versus 10 days in those without SSI ($P < 0.01$). Mortality was 4.6% in SSI patients (9/194) versus 2.4% (205/8465) in patients without infection ($P = 0.06$); further surgery was required in 45.2% of the SSI patients (only two patients without SSI underwent an additional surgery).

Comparing the patients with deep-organ space sternal SSI versus the patients with superficial SSI, there were no differences with respect to the interval to diagnosis, causative micro-organisms or NNIS score. However, patients with deep SSI tended to have a longer length of hospital stay (32 days versus 19 days, $P < 0.001$), a longer duration of follow-up (45 days versus 30 days, $P < 0.001$), a higher mortality (9.6% versus 0%), and a higher risk of revision surgery (67.8% versus 20%, $P < 0.001$).

Microbiology

Micro-organisms were isolated in 144 (74%) patients: 35% coagulase negative-staphylococci ($N = 51$), 23% *Staphylococcus aureus* ($N = 33$) including five methicillin-resistant *S. aureus* (MRSA), 6% *Escherichia coli* ($N = 8$), 5% *Pseudomonas aeruginosa* ($N = 7$), 3% *Enterococcus faecalis* ($N = 4$), 3% other Gram-positive bacteria ($N = 4$), 2% *Citrobacter koseri* ($N = 3$), 2% *Serratia* spp. ($N = 2$), and 8% other Gram-negative bacteria ($N = 11$). Five patients had two micro-organisms identified, 15 had three (10%). Cultures were negative in eight patients, not performed in five patients and information was missing in 37.

S. aureus was found in six out of nine patients (67%) who developed SSI and died before discharge, including two patients with MRSA. No trends between years were observed.

Results of multivariate analysis are presented in Table II. Model A was an empty model with no explanatory variable. The part of the residual variance attributed to ward level was 7% and was significantly different from zero (i.e. 7% of total variability of the outcome variable was explained by differences between wards). In a model with patients' characteristics only (model B), a higher probability of SSI was associated with the duration of preoperative hospitalization, the duration of follow-up, the duration of surgery >75 th percentile. ASA score, wound contamination class, sex, and age were not significantly associated with SSI. Model B included the separated components of NNIS score and was preferred to a model including NNIS [NNIS score: OR: 1.67 (95% CI 1.23–2.270); MOR:

1.52; ICC: 0.06]. The residual heterogeneity between wards (MOR: 1.53) was equal to the duration of preoperative hospitalization (OR: 1.57).

In univariate analysis, only the ward SSI rate was significantly associated with higher probability of SSI. In a multivariate model with both patient and ward characteristics (model C), a higher probability of SSI was associated with the duration of surgery >75th percentile and the ward SSI rate.

Cost

The total additional cost of SSI for facilities was estimated to be €291,000 for 94 patients during the four years studied. If hospital financing did not reimburse a part of the costs of the SSI, the costs would have increased to €1,034,000 for the facilities.

Discussion

This analysis using a national dataset found a 2.2% incidence rate of SSI after valvular and CABG surgery within the first 30 days following surgery. This result is consistent with previous nationwide studies.^{5,6} A significant heterogeneity of SSI occurrence between wards was found. This is, to our knowledge, the first nationwide study showing the contribution of ward risk factors in cardiac surgery SSI.

Several limitations to the present study should be noted. Whereas the protocol recommended a minimum follow-up of 30 days, methods differed between the wards.³ Despite this issue, we believe that underdiagnosis of infection was unlikely since no patient developed an SSI after 22 days.^{19,20} The study was restricted to the wards that carried out more than 10 cardiac procedures in order to prevent the great variability of small samples which could generate bias in the multilevel analysis. An additional issue which could have affected analysis was the fact that only one type of procedure could be defined on the surveillance form. Surgeons had to choose between CABG or valvular procedure, even when patients underwent a combined procedure. Nevertheless, our findings were in line with literature showing a higher rate of SSI after CABG than after valvular repair.^{6,14,21}

This study also confirmed the impact of several previously identified individual risk factors. The impact of the preoperative length of stay was confirmed as noted in previous reports. This phenomenon is probably multifactorial, including increased colonization with hospital pathogens or progressive impairment of the patient's nutritional status and is unlikely to be impacted by interventions.²³ Since this factor disappeared in the model along with ward characteristics, further investigation of the phenomenon should be carried out.

Duration of surgery may reflect either the patient's preoperative morbidity, operating room logistics, or difficulties during the surgery.²¹ Cristofolini *et al.* pointed out that the ASA risk group may not be applicable in cardiac surgery since almost all patients exhibit an ASA

score ≥ 3 , which was the case in our study.²⁴ The wound contamination class seems irrelevant in the types of cardiac surgery we studied; the NNIS score index should therefore not be used to compare SSI rates after cardiothoracic operations among surgeons or institutions.²⁵ The logistic EuroSCORE I and II or the Society of Thoracic Surgeons risk score (STS score) should be more appropriate than NNIS for cardiac surgery but was not available at the time of the study.²⁶

Coagulase-negative staphylococci and *S. aureus* were implicated in half of the cases of SSIs. These organisms have various virulence factors and are usually found on the skin and the environment which can explain their predominance in SSI after cardiac surgery.^{27,28} The importance of these pathogens has led to recommendations for the use of nasal mupirocin for all cardiac surgery cases.²⁹

We used a multilevel modelling technique to take into account the hierarchical data structure and the correlation of within-group observations. This study showed a significant correlation of infections and the ward location of the patient after adjusting for patient-level variables. In an empty model, we found a between-patient and between-ward heterogeneity. MOR indicated that the ward of hospitalization would be relevant for understanding variations of the individual probability of acquiring SSI. Healthcare-associated infection prevention practices may explain variation in rates between healthcare facilities. A higher incidence of SSI in the ward was associated with higher probability of SSI for a patient: this relationship could be a reflection of the ward ecology, colonization pressure or suboptimal compliance with infection control measures, none of which was could be evaluated in this survey. Furthermore, organization and patient safety culture differences may also have a role.³⁰ Although the use of intraoperative antibiotic bone paste and the use of antibiotic-impregnated sutures were associated with a lower risk of developing SSIs, the differences were not significant.²² SSI surveillance is considered to be an effective strategy for reducing SSI incidence, as well as a tool for surgical staff to promote awareness and prevention, but French SSI surveillance was unable to identify specific reasons for ward-related infection risks. Indeed, the findings of our study suggest that more precise and detailed ward characteristics should be included in future cardiac surgery SSI studies in the hope of identifying interventions which could further decrease the risk of these infections.

The present study provided clear evidence of the impact of ward-level variables on the occurrence of SSI in CABG and valvular surgery. Although patient risk factors were more strongly associated with the SSI occurrence, the impact of ward characteristics was not negligible. Ward risk factors should be evaluated by the surgery team and infection control teams by performing root cause analysis to improve patients' quality of care.^{31,32}

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Conflict of interest statement

None declared.

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Table I

Univariate analysis of patients with and without surgical site infection (SSI) after coronary artery bypass graft or valvular surgery (SSI-RAISIN 2008–2011)

Variable	Infection		N	SSI rate	P-value
	SSI (N = 194)	Control group (N = 8465)			
Mean ± SD age (years)	68.2 ± 11.1	69.6 ± 11.1	8659		0.07
Mean ± SD time of patient follow-up (days)	38.2 ± 30.8	30.8 ± 25.5	8659		0.001
Male sex	132 (68%)	5816 (69%)	8435		0.95
Preoperative length of stay (>2 days)	67 (35%)	2195 (26%)	8530		0.01
Emergency surgery	7 (4%)	260 (3%)	8094		0.77
NNIS score			8110		0.001
0	5 (2.6%)	314 (3.7%)		1.6	
1	113	5925		1.9	
2	58	1675		3.5	
3	1	19		5.3	
ASA score			8175		0.09
1	1	67		1.5	
2	6	384		1.6	
3	133	6308		2.1	
4	40	1182		3.4	
5	1	53		1.9	
Wound contamination class			8402		0.26
1	180	8027		2.2	
2	2	112		1.8	
3	1	46		2.2	
4	1	33		3.0	
Duration of surgery >75th percentiles	61 (31%)	1830 (22%)	1891		0.01

NNIS, National Nosocomial Infections Surveillance system; ASA, American Society of Anesthesiologists.

Table II

Multivariate analysis of risk factors for surgical site infection after coronary artery bypass graft or valvular surgery (SSI-RAISIN 2008–2011)

Variable	Model A	Model B	Model C
Intercept	−3.881 (0.118)	−4.278 (0.433)	−4.524 (0.463)
Patient characteristics			
Age ≥65 years		0.755 (0.550–1.035)	0.988 (0.974–1.001)
Male sex		1.023 (0.729–1.436)	1.018 (0.725–1.429)
Duration of preoperative hospitalization ≥48 h		1.573 (1.138–2.173)	1.462 (1.062–2.012)
Duration of postoperative follow-up		1.007 (1.001–1.013)	0.898 (0.660–1.219)
ASA score >2		1.274 (0.583–2.778)	1.309 (0.593–2.869)
Wound contamination class >2		0.880 (0.209–3.775)	0.738 (0.174–3.131)
Duration of surgery >75th percentile		1.820 (1.299–2.550)	1.756 (1.275–2.416)
Ward characteristics			
Percentage of NNIS-0 patients			1.006 (0.965–1.048)
No. of valvular and CABG surgeries per month			1.000 (0.992–1.007)
Ward SSI rates			1.724 (1.480–2.000)
Median OR (95% CI)	1.59 (1.431–1.791)	1.53 (1.451–1.760)	1.05 (1.010–1.08)
Intraclass correlation coefficient	0.067	0.058	0.001

NNIS, National Nosocomial Infections Surveillance system; ASA, American Society of Anesthesiologists; CABG, coronary artery bypass graft; OR, odds ratio; CI, confidence interval; NNIS-0 patient: ASA score ≤2 + wound contamination class ≤2 + duration of surgery ≤75th percentile.

Figure 1. Distribution of the 2008–2011 surgical site infection (SSI) rate in valvular and coronary artery bypass graft surgery, French national SSI Surveillance ISO RAISIN ($N=39$ wards).

Author queries

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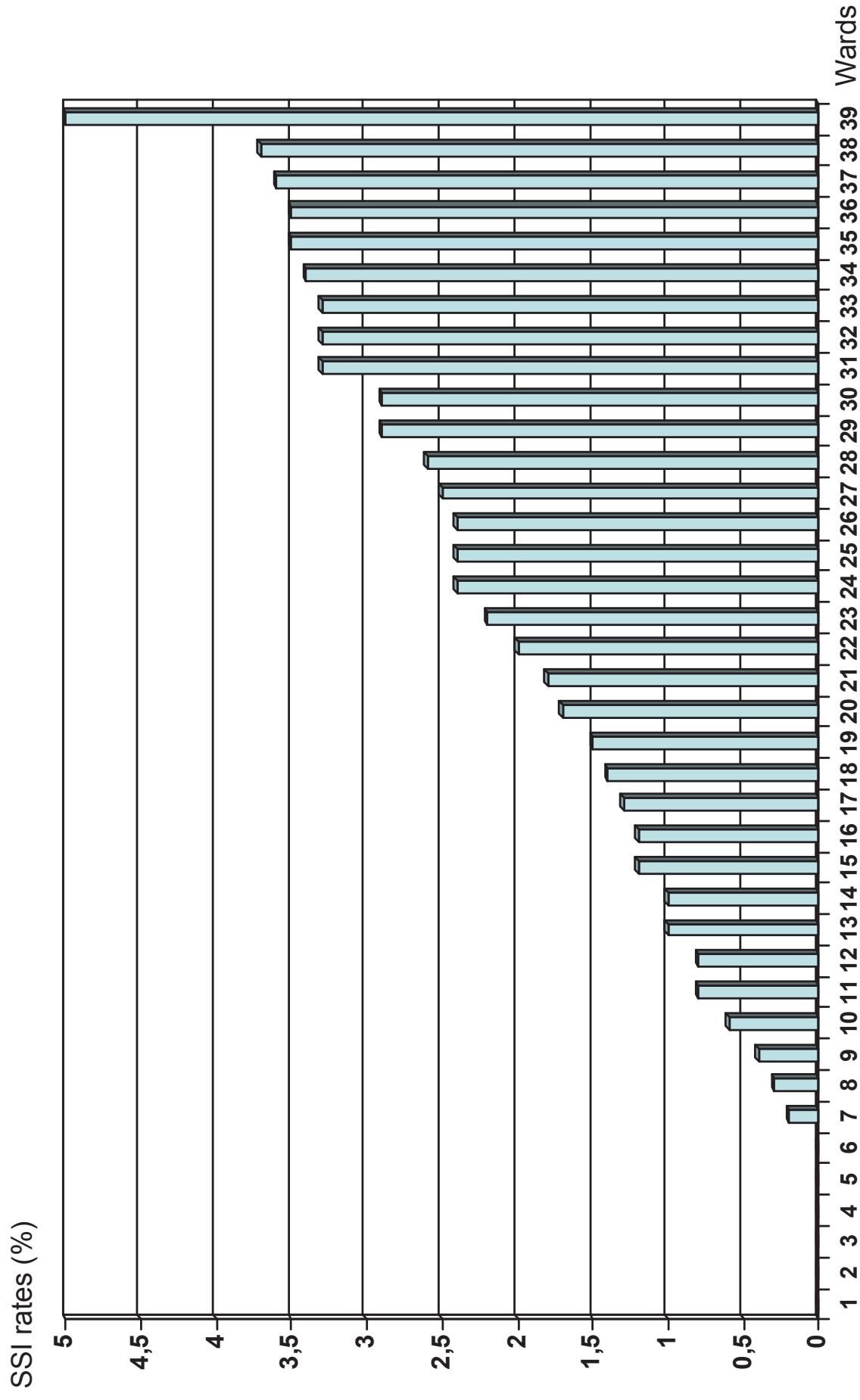


Figure 1.