Temporal Trends in the Incidence of Surgical Site Infections in Patients Undergoing Coronary Artery Bypass Graft Surgery: A Population-Based Cohort Study, 1993 to 2008

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Abstract

Objective: To determine the incidence of and temporal trends in surgical site infections (SSIs) in patients underoing coronary artery bypass graft (CABG) surgery.

Methods: A population-based cohort study was conducted to describe the epidemiologic features of SSI in Olmsted County, Minnesota, between January 1, 1993, and December 31, 2008, using the Rochester Epidemiology Project. Period-specific incidence rates (in-hospital or within 30 days outside the hospital) were calculated. Logistic regression analysis was used to adjust for potential confounders that could affect temporal trends in SSI incidence rates.

Results: During the 16-year study, of 1424 residents of Olmsted County who underwent CABG surgery, 1189 (83%) had isolated CABG and 235 (17%) had combined CABG and valve surgery. The overall SSI incidence rate was 7.0% (95% confidence interval [CI], 5.7%-8.4%). The incidence rate of superficial sternal SSI was 2.0% (95% CI, 1.2%-2.7%) and of deep sternal SSI was 1.5% (95% CI, 0.9%-2.2%). The leg harvest site infection rate was 3.6% (95% CI, 2.6 %-4.5%). The incidence rate decreased over time with a statistically significant linear trend. The adjusted odds ratio (95% CI) of SSI showed a decreasing linear trend: 0.39 (0.19-0.81) vs 0.50 (0.27-0.93) vs 0.83 (0.48-1.42) vs reference for 2005-2008 vs 2001-2004 vs 1997-2000 vs 1993-1996.

Conclusion: In this population-based surveillance study of patients undergoing CABG surgery, the incidence of SSI decreased markedly between 1993 and 2008 in patients in Olmsted County. The factors responsible for this decrease are the focus of ongoing investigations.

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Coronary artery bypass graft (CABG) surgery improves the overall quality of life in patients with coronary artery disease.[1] However, complications of CABG surgery, such as surgical site infection (SSI), particularly deep sternal SSI, are a cause of substantial morbidity and mortality and significant hospital costs.[2,3] Furthermore, the prevalence of CABG surgery in patients at high risk for infection is increasing due to an aging US population and the frequency of conditions conferring cardiovascular and infectious risks (obesity and diabetes mellitus) in the population.[4] The mortality rate in patients with sternal SSI has ranged from 14% to 42%.[3,5]

Coronary artery bypass graft surgery is unique because it includes sternal and vascular harvest site incisions that can result in SSIs at different sites. Thus, interpretation of SSI rates must assess those occurring at each site. Few studies have been performed to examine harvest site infections. In an earlier study, DeLaria et al[6] found that leg wound complications resulted in a mean of 12 additional hospital days and increased cost by $9900. The bulk of attention has focused on deep sternal SSI and mediastinitis because of their potential for causing serious morbidity and mortality, although graft harvest site infections may be more common.[3,5,7,8] Trick et al[9] found that vascular harvest site infections are common after CABG surgery, with a rate greater than 15%.

The incidence of superficial SSI in sternotomies should be similar to that of any clean surgical procedure, ie, approximately 2%. Nonetheless, the infection rate can be 3-fold higher in patients with heart disease due, in large part, to the multiple comorbid conditions that typically characterize these patients.[10-12] The reported incidence of deep SSI has ranged from 0.5% to 6.8%.[9,13,14] This variation may be explained by differences in study design, patient profile, types of surgical procedures performed, and definition of SSI because some studies also include superficial SSI, consequently reporting

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a higher incidence of SSI.[14,15] However, no temporal trends in incidence have been reported in a US population. We, therefore, conducted a retrospective population-based cohort study using standard criteria established by the Centers for Disease Control and Prevention (CDC) to describe the epidemiologic features of SSI after CABG surgery in Olmsted County, Minnesota, during a 16-year period (1993-2008).

METHODS

Setting and Population

The population of Olmsted County is served by a largely unified medical care system that has accumulated comprehensive clinical records since 1966.[15] Olmsted County (2010 population, 144,248) is located 90 miles southeast of Minneapolis/St Paul. Approximately 74% of the county population resides within the city limits of Rochester, Minnesota, the centrally located county seat. The population is mainly of white race/ethnicity (83.4%) and is largely middle class.[16] The characteristics of the Olmsted County population are similar to those of the US non-Hispanic white population except for a higher proportion of working adults being employed in the health care industry.

Epidemiologic research in Olmsted County is feasible because the city and county are relatively isolated from other urban centers, and nearly all medical care is provided to local residents by a handful of providers.

The Rochester Epidemiology Project (REP) is a medical records linkage system that indexes the medical records of all individuals seen by a health care provider and residing in Olmsted County. For each patient, there exists a single dossier into which medical diagnoses, surgical interventions, and other key information from medical records are regularly abstracted and entered into computerized indexes with use of the *International Classification of Diseases, Ninth Revision, Clinical Modification*.[16,17] The REP allows investigators to obtain patient data from their outpatient (office, urgent care, and emergency department) and hospital contacts across all local medical facilities, regardless of where the care was provided and of insurance status. Thus, the REP allows investigators to conduct long-term population studies of disease incidence.

Coronary Procedures

Since 1955, Mayo Clinic has maintained an index of surgical procedures that can be queried electronically. This index allowed us to identify all the patients who underwent CABG surgery between January 1, 1993, and December 31, 2008. Because Mayo Clinic is the sole provider of CABG surgery in Olmsted County, this case-finding approach resulted in the complete ascertainment of all CABG procedures performed in the county.

Case Ascertainment

After this study received approval from the Mayo Clinic Institutional Review Board and the Institutional Review Board of Olmsted Medical Center, SSI cases were initially identified using *International Classification of Diseases, Ninth Revision, Clinical Modification* codes 998.51and 998.59 and *Hospital International Classification of Diseases Adapted* codes 09985110, 09985210, 09985211, 09985212, 09985213, 09985214, 09985230, 09985310, 09985411, 09985412, and 09985413. Also, to enhance the completeness of case ascertainment, data from the cardiovascular division database at Mayo Clinic, which are regularly submitted to the Society of Thoracic Surgeons (STS) national database, were used. The cohort included all adults (≥18 years) who were residents of Olmsted County for at least 1 year before surgery and who underwent either isolated CABG surgery or combined CABG/valve surgery between 1993 and 2008.

Once the diagnosis of each potential case was confirmed and residency established, the complete inpatient and outpatient medical record was reviewed by the primary investigator (F.A.A.). Pertinent information was abstracted using a standardized data form.

Case Definition

Superficial and deep sternal SSIs and leg harvest site infections (LHSIs) were defined according to the guidelines outlined by the CDC.[18]

Statistical Analyses

For incidence rate calculation, all adult (≥18 years) residents of Olmsted County who underwent CAGB surgery between January 1, 1993, and December 31, 2008, were considered at risk. Patients with an SSI within 30 days after CABG surgery were identified. Deep incisional sternal site and organ/space infections were combined into a single category. Demographic and baseline clinical characteristics and the outcomes of infections for all patients undergoing CABG surgery are summarized using appropriate descriptive statistics. Demographic, preoperative, intraoperative, and postoperative measures were compared between those who had infections (either sternal SSIs or LHSIs) and those who did not. The overall incidences of infections (either sternal SSIs or LHSIs), sternal SSIs, and LHSIs in the CABG cohort were estimated, with corresponding 95% confidence intervals (CIs). In addition to the overall estimate, we divided the 16-year study period into four 4-year periods (1993-1996, 1997-2000, 2001-2004, and 2005-2008) and calculated the incidences of the infections separately for each of these 4-year intervals, with corresponding 95% CIs. Initially, the score test for trend of odds was used to investigate time trend in odds of infection; thereafter, logistic regression analysis was performed with the dependent variable being infected (yes/no) and the 4 periods (4 years each) as independent variables, with other covariates entered into the model to obtain an adjusted odds ratio associated with each study period. The final logistic model was fitted using the stepwise regression (insertion/deletion) method, entering all significant covariates into the model initially and retaining those in the final model that were observed to be significant at a 5% level of significance. All the statistical analyses were performed using a statistical software program (Stata, version 10; StataCorp LLP).

RESULTS

During the 16-year study, of 1424 residents of Olmsted County who underwent CABG surgery, 1189 (83%) had isolated CABG surgery and 235 (17%) had combined CABG and valve surgery. Table 1 summarizes the demographic and clinical characteristics of the entire cohort according to SSI status. The mean ± SD age of the cohort was 66.7±11.1 years, and 24.7% were women. The overall SSI incidence rate was 7.0% (95% CI, 5.7%-8.4%) (Table 2). The incidence rate of superficial sternal SSI was 2.0% (95% CI, 1.2%-2.7%) and of deep sternal SSI was 1.5% (95% CI, 0.9%-2.2%). The LHSI rate was 3.5% (95% CI, 2.6%-4.5%).

Period-specific incidence rates for 1993-1996, 1997-2000, 2001-2004, and 2005-2008 are compared in Table 2. The incidence rate of overall SSI decreased over time in a linear trend, which was statistically significant at $P<.05$. However, superficial sternal SSI rates did not consistently show this decreased trend across the 4 study periods. Table 3 displays the odds ratios associated with each period after adjusting for body mass index (calculated as the weight in kilograms divided by the height in meters squared), intraoperative cryoprecipitate transfusion, hospital readmission, and length of hospital stay. Again, it showed a decreasing linear trend with a statistically significant reduction in the last 2 periods. Table 4 summarizes the distribution of SSI causative organisms. Of the 100 patients with SSIs, no culture was performed in 38, and we found that surgeons tend to diagnose and treat most superficial SSIs without microbiologic culture being performed. Most SSIs (n=21) were due to coagulase-negative staphylococci.

DISCUSSION

The results of this population-based survey of SSI complicating CABG surgery deserve further comment. The overall incidence (7.0%) was higher than expected for "clean" cases and was primarily due to the number of harvest site infections. The incidence of SSI varies depending on the infection definition and type of surgery. In 3 previous studies,[5,19,20] for example, strict definitions were used and likely underestimated the true incidence of SSI complicating CABG surgery. Although the CDC criteria used in this survey are mainly considered a surveillance definition, their definition was intended to define clinical syndromes for making therapeutic decisions, and, thus, they may have missed some SSI cases.

Published population-based and multicenter data on SSI incidence after CABG surgery are summarized in Table 5. Steingrimsson et al[21] conducted a population-based study in Iceland that included only patients with deep SSI with an incidence rate slightly higher (2.5%) than what we observed. In the Netherlands, Manniën et al[22] conducted surveillance across multiple centers and found an overall SSI rate of 5.6%, a superficial sternal SSI rate of 1.1%, a deep sternal SSI rate of 1.3%, and an LHSI rate of 3.2%. In this nationwide epidemiologic study, a surveillance period of 42 days instead of 30 days was chosen, and 13% of recorded SSIs were diagnosed 30 to 42 days postoperatively. In addition, they used postdischarge surveillance of SSI after cardiothoracic procedures to minimize the risk of missing cases. Because the surveillance was elective for LHSI and mandatory for sternal SSI, it is conceivable that some LHSI cases were missed. The first Norwegian study of national baseline incidence rates of SSI after CABG surgery performed between 2005 and 2009 was conducted by Berg et al.[23] The overall SSI incidence rate was 14%, the sternal SSI rate was 5.1%, and the LHSI rate was 8.9%. However, the surveillance system used was not yet validated, and numbers of participating hospitals varied. In the United States, Fowler et al[4] used clinical information obtained from the STS national cardiac database of almost two-thirds of all US bypass procedures (300,000 patients) performed during 2002-2003. They considered only deep sternal SSIs and LHSIs and reported their incidence rates to be 0.9% and 1.1%, respectively. The combined incidence rate was approximately 2.1%. These low rates of deep sternal SSI and LHSI may reflect, in part, the large geographically diverse population in the STS database, which increases generalizability and also uniformity in identification of infectious complications of CABG surgery in the STS database. Moreover, rates of deep sternal SSI may be higher in centers with active infection control surveillance rather

TABLE 1. Demographic and Clinical Characteristics of 1424 Patients Who Underwent CABG Surgery With or Without Valve Surgery, Olmsted County, Minnesota, 1993-2008[a,b]

Characteristic	No. of patients	Patients without SSI (n=1324)	Patients with SSI (n=100)	*P* value
Age (y), mean ± SD	1424	66.7±11.2	67.7±9.8	.38
Female	1424	320 (24.2)	32 (32.0)	.08
Race/ethnicity	1423			.80
White		1286 (97.1)	98 (99.0)	
Black		9 (0.7)	1 (1.0)	
Hispanic		9 (0.7)	0	
Asian		16 (1.2)	0	
Native American		3 (0.2)	0	
BMI, mean ± SD	1424	28.8±4.9	31.4±6.5	<.001
Presurgery length of hospital stay (d), mean ± SD	1420	2.1±3.5	2.8±3.3	.06
Length of hospital stay (d), mean ± SD	1424	7.7±7.1	16.1±20.8	<.001
Smokers	1423	892 (67.4)	66 (66.0)	.77
Diabetes mellitus	1424	362 (27.3)	39 (39.0)	.01
Ejection fraction category	1424			.78
>50%		889 (67.2)	64 (64.0)	
35-50%		323 (24.4)	26 (26.0)	
<35%		112 (8.5)	10 (10.0)	
Dialysis	1424	13 (1)	1 (1.0)	>.99
Chronic obstructive lung disease	1424	132 (10.0)	13 (13.0)	.33
Immunosuppressive treatment	1424	48 (3.6)	8 (8.0)	.03
Peripheral vascular disease	1424	248 (18.7)	26 (26.0)	.08
Cerebrovascular disease	1424	183 (13.8)	19 (19.0)	.15
Cerebrovascular accident	1424	97 (7.3)	7 (7.0)	.90
Previous CABG	1424	72 (5.4)	7 (7.0)	.51
Preoperative myocardial infarction	1424	596 (45.0)	54 (54.0)	.08
Preoperative unstable angina	1422	455 (34.4)	30 (30.0)	.37
Congestive heart failure	1424	191 (14.4)	21 (21.0)	.08
NYHA class	1419			.43
I		49 (3.7)	4 (4.0)	
II		181 (13.7)	8 (8.0)	
III		549 (41.6)	46 (46.0)	
IV		540 (41.0)	42 (42.0)	
Emergency surgery	1424	94 (7.1)	5 (5.0)	.43
American Society of Anesthesiologists physical status class	1391			.49
2 (mild systemic disease, no functional limitation)		9 (0.7)	1 (1.0)	
3 (severe systemic disease, definite functional limitation)		1192 (92.2)	87 (88.8)	
4 (severe systemic disease that is a constant threat to life)		92 (7.1)	10 (10.2)	
Operative category	1421			.21
CABG		1110 (83.8)	79 (79.0)	
CABG + valve		214 (16.2)	21 (21.0)	

Continued on next page

TABLE 1. Continued

Characteristic	No. of patients	Patients without SSI (n=1324)	Patients with SSI (n=100)	*P* value
Use of venous graft from the leg	1417	1122 (85.2)	98 (98.0)	<.001
Radial artery use	1417	89 (6.8)	4 (4.0)	.28
Use of skeletonization as the harvested method for IMA	1424			.58
None		1235 (93.3)	95 (95.0)	
Single		54 (4.1)	2 (2.0)	
Both		35 (2.6)	3 (3.0)	
IMA use	1424			.02
None		107 (8.1)	15 (15.0)	
Left		1058 (79.9)	77 (77.0)	
Right		8 (0.6)	2 (2.0)	
Both		151 (11.4)	6 (6.0)	
No. of IMA grafts	1424			.02
0		108 (8.2)	15 (15.0)	
1		1067 (80.6)	80 (80.0)	
2		149 (11.3)	5 (5.0)	
Intraoperative cryoprecipitate transfusion	1423	13 (1.0)	3 (3.0)	.06
Reexploration-	1424			.60
For bleeding		50 (3.8)	5 (5.0)	
For another reason		9 (0.7)	0	
Readmission within 30 d	1412	182 (13.9)	36 (36.4)	<.001

[a] BMI = body mass index (calculated as weight in kilograms divided by height in meters squared); CABG = coronary artery bypass graft surgery; IMA = internal mammary artery; NYHA = New York Heart Association; SSI = surgical site infection.
[b] Data are presented as No. (percentage) unless otherwise indicated.

than voluntary reporting, as occurs with the STS database. The lower rate of deep sternal SSIs may also reflect that the STS database primarily captures acute events, whereas some infections may become apparent much later after surgery.[4] The previously mentioned studies found a large range of SSI incidences after cardiovascular procedures. However, comparisons should be performed carefully because of differences in SSI criteria, durations of follow-up, types of cardiac surgery, and methods of postdischarge surveillance. Owing to these limitations, the focus should be on following SSI incidence time trends within a country instead of on comparing countries with each other.

In addition, these data showed that incidence trends for overall SSIs were consistently decreasing

TABLE 2. Temporal Trends in the Incidence of All SSIs During 16 Years, Olmsted County, Minnesota[a,b]

		Study period				
Type of SSI	1993-2008 (N=1424)	1993-1996 (n=401)	1997-2000 (n=411)	2001-2004 (n=337)	2005-2008 (n=275)	*P* value
All	100 (7.0) [5.7-8.4]	36 (9.0) [6.4-12.3]	30 (7.3) [5.2-10.5]	21 (6.2) [3.9-9.4]	13 (4.7) [2.3-7.5]	.02
Superficial sternal	28 (2.0) [1.2-2.7]	6 (1.5) [1.0-3.2]	10 (2.4) [1.2-4.4]	3 (0.9) [0.2-3.0]	9 (3.3) [1.5-6.1]	.34
Deep sternal	22 (1.5) [0.9-2.2]	12 (3.0) [1.6-5.2]	2 (0.5) [0.1-1.7]	7 (2.1) [1.0-4.0]	1 (0.4) [0.0-2.0]	.04
Leg harvest	50 (3.5) [2.6-4.5]	18 (4.5) [2.7-7.0]	18 (4.4) [2.6-6.8]	11 (3.3) [1.9-6.2]	3 (1.1) [0.2-3.2]	.02

[a] SSI = surgical site infection.
[b] Data are given as No. (percentage) [95% confidence interval].

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TABLE 3. Unadjusted and Adjusted ORs of All Surgical Site Infections for the 3 Periods Using the First Period (1993-1996) as a Reference

Variable	Unadjusted OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Study period				
1993-1996	1 (Reference)		1 (Reference)	
1997-2000	0.83 (0.50-1.37)	.46	0.83 (0.48-1.42)	.49
2001-2004	0.67 (0.38-1.17)	.17	0.50 (0.27-0.93)	.03
2005-2008	0.46 (0.24-0.91)	.03	0.39 (0.19-0.81)	.01
Readmission	NA	NA	3.81 (2.38-6.10)	<.001
Length of hospital stay	NA	NA	1.06 (1.04-1.08)	<.001
BMI	NA	NA	1.10 (1.06-1.15)	<.001
Intraoperative cryoprecipitate transfusion	NA	NA	4.58 (1.20-17.53)	.03

BMI = body mass index; CI = confidence interval; NA = not applicable; OR = odds ratio.

over time and that this finding could be attributable to multiple factors. Most important, it could be related to improvement in infection control measures that include judicious use of prophylactic antibiotics, with an effective screening and surveillance strategy. Also, several innovations in coronary revascularization surgery, such as minimally invasive CABG and "off-pump" operations, have been adopted widely in the past decade with the promise of improved clinical outcomes compared with older revascularization technologies and techniques. Furthermore, endoscopic vein harvest has been used increasingly as an alternative to the open technique, and this has led to a significant decrease in the incidence of leg incision complications, including SSIs.[24,25]

Surgical site infection had been diagnosed in 50% of patients in the outpatient setting, with an overall mean time to onset of 13 days; 34% of those who developed an SSI required hospital readmission. This study demonstrated the importance of follow-up to ensure that all SSIs are captured and is consistent with findings from previous investigations that found that 68.4%[22] and 95%[23] of SSIs were diagnosed after hospital discharge.

Coagulase-negative staphylococci were the most common pathogens (21%) in this study. In contrast, *Staphylococcus aureus* was predominant in 2 other investigations.[21,22] This difference could be due, in part, to the routine use of mupirocin for methicillin-resistant *S aureus* decolonization that was adopted by the Division of Cardiovascular Surgery, Mayo Clinic, in 2002 for each patient undergoing CABG surgery.

This study has several important strengths. To our knowledge, it is the first population-based study to examine temporal trends in all types of SSIs in a geographically defined US population. The essen-

TABLE 4. Microbiologic Characteristics of the SSIs

	SSI (No.)			
Causative pathogen	Superficial sternal (n=28)	Deep sternal (n=22)	LHSI (n=50)	Total (N=100)
Coagulase-negative staphylococci	5	13	3	21
Staphylococcus aureus	3	5	4	12
Enterococcous species	1	1	2	4
Gram-negative bacilli	1	3	0	4
Polymicrobial	1	0	9	10
Other	0	0	2	2
Culture negative	7	0	2	9
Culture not performed	10	0	28	38

LHSI = leg harvest site infection; SSI = surgical site infection.

TABLE 5. General Characteristics of Population-Based and Multicenter Cardiac Surgery–Related SSI Studies

Reference, year	Country	Study period	Type of surgery	Type of SSI	Case definition	Case ascertainment	Incidence rate (%)
Steingrimsson et al,[21] 2008	Iceland	1997-2004	All open heart surgery	Deep sternal	CDC	2 Different registries	2.5
Manniën et al,[22] 2011	The Netherlands	2002-2007	CABG CABG + valve Isolated valve	All	CDC	Use of surveillance data	SSI = 5.6 Superficial sternal SSI = 1.1 Deep sternal SSI = 1.3 LHSI = 3.2
Berg et al, [23] 2011	Norway	2005-2009	CABG	All	CDC	National surveillance data	SSI = 14 Sternal SSI = 5.1 LHSI = 8.9
Fowler et al,[4] 2005	United States	2002-2003	Isolated or combined CABG	Deep sternal and LHSI	≥1 of the following: wound opened with excision of tissue, positive culture, or antibiotic treatment	STS adult cardiac database	Deep sternal SSI = 0.9 LHSI = 1.1

CABG = coronary artery bypass graft; CDC = Centers for Disease Control and Prevention; LHSI = leg harvest site infection; SSI = surgical site infection; STS = Society of Thoracic Surgeons.

tially complete ascertainment of all SSI cases by active search in an established medical records linkage system for a population of known size and age distribution allowed unbiased estimation of the incidence rate of SSI. Furthermore, to reduce the risk of incomplete SSI case ascertainment, we used the institutional STS adult cardiac surgery database. Data completeness in the STS database is high and extremely accurate.[26]

Limitations of this study include its retrospective nature, which relied on the accuracy and completeness of clinical records, and the fact that it is subject to several biases, including reviewer bias. Also, the race/ethnicity of the Olmsted County population is 90% white, suggesting that the results of this study may not be applicable to other populations. However, the homogenous nature of the population limits external biases, and, thus, these observations reflect a pure assessment of the temporal trends of SSI in a preserved population.

CONCLUSION

In this first population-based surveillance study of patients undergoing CABG surgery, we found that the incidence of SSI decreased markedly between 1993 and 2008 in Olmsted County patients. The factors responsible for this apparent decrease are the focus of ongoing investigations.

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Drs Alasmari and Tleyjeh contributed equally to this work.

Abbreviations and Acronyms: **CABG =** coronary artery bypass graft; **CDC =** Centers for Disease Control and Prevention; **LHSI =** leg harvest site infection; **REP =** Rochester Epidemiology Project; **SSI =** surgical site Infection; **STS =** Society of Thoracic Surgeons

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