Evolving trends of reoperative coronary artery bypass grafting: An analysis of the Society of Thoracic Surgeons Adult Cardiac Surgery Database

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Objective: The present study evaluated the evolving trends and outcomes of patients undergoing isolated reoperative coronary artery bypass grafting at Society of Thoracic Surgeons Adult Cardiac Surgery Database-participating institutions.

Methods: From 2000 to 2009, 72,431 patients underwent isolated reoperative coronary artery bypass grafting and 1,497,254 patients underwent isolated primary coronary artery bypass grafting at Society of Thoracic Surgeons-participating institutions. The demographics, operative characteristics, and risk-adjusted postoperative outcomes were assessed and compared during the study period.

Results: As a percentage of overall coronary artery bypass grafting volume, reoperative coronary artery bypass grafting decreased from 6.0% (8820/137,267) in 2000 to 3.4% (5734/160,997) in 2009. The unadjusted operative mortality declined from 6.1% (542/8820) in 2000 to 4.6% (261/5734) in 2009 ($P < .05$). Patients now more frequently present with left main disease (35.1% vs 25.7%; $P < .05$), myocardial infarction (60.9% vs 55.9%; $P < .001$), and heart failure (18.4% vs 14.2%; $P < .001$). Patients also now present more frequently for urgent or emergent surgery (51.6% vs 39%; $P < .001$) and after previous percutaneous coronary intervention (51% vs 35%; $P < .001$). They also have a greater incidence of other comorbidities such as increased weight (88 vs 84 kg; $P < .001$), diabetes (42.5% vs 31.7%; $P < .001$), hypertension (90.9% vs 73.4%; $P < .001$), hypercholesterolemia (90.9% vs 73.4%; $P < .001$), renal failure (2.2% vs 0.7%; $P < .001$), and cerebrovascular disease (12.4% vs 8.5%; $P < .001$). Risk-adjusted mortality decreased from 6.0% to 4.6%, a relative risk reduction of 23.7% ($P < .001$). Risk-adjusted postoperative stroke decreased from 1.9% to 1.6% ($P < .001$).

Conclusions: Surgical coronary revascularization has evolved during the past decade, with reoperative coronary artery bypass grafting now uncommonly performed in contemporary practice. Despite treating patients with more complex coronary artery disease and greater medical comorbidities, significant improvements have occurred in operative morbidity and mortality in this challenging population. (J Thorac Cardiovasc Surg 2013;145:364-72)

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Coronary artery bypass grafting (CABG) remains the reference standard treatment of patients with complex coronary artery disease.¹⁻³ We recently analyzed the contemporary patient characteristics and postoperative outcomes for 1.5 million isolated CABG operations at the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database-participating institutions.⁴ In that study, we found that the risk profiles of patients undergoing isolated CABG have changed from 2000 to 2009, with patients currently presenting with a greater number of medical comorbidities, such as diabetes, hypertension, and renal failure. Despite this, significant improvements have occurred in morbidity and mortality after isolated CABG during the past decade. In 2009, the risk-adjusted CABG mortality was 1.7%, representing a relative risk reduction of 22.8% compared with the risk-adjusted CABG mortality in 2000. Reoperative CABG involves greater operative complexity and is associated with greater operative morbidity and mortality than primary CABG.⁵ Although patient comorbidities, medical management, and percutaneous therapies have evolved, the contemporary practice and outcomes of reoperative CABG have not

Abbreviations and Acronyms

ACE	= angiotensin-converting enzyme
CABG	= coronary artery bypass grafting
IABP	= intra-aortic balloon pump
IMA	= internal mammary artery
PCI	= percutaneous coronary intervention
STS	= Society of Thoracic Surgeons

been studied. The present study evaluated trends in patient characteristics and outcomes for patients undergoing isolated reoperative CABG at STS Adult Cardiac Surgery Database-participating institutions. We compared these outcomes over time and with the contemporary primary CABG outcomes published in our previous study.⁴

MATERIALS AND METHODS

Study Population

The study population consisted of all patients older than 18 years who underwent isolated primary or reoperative CABG at STS Adult Cardiac Surgery Database-participating hospitals from January 1, 2000 to December 31, 2009. Patients who underwent isolated reoperative CABG were those who had undergone previous CABG at any point previously. Patients were excluded if they had missing data on age, gender, or acuity status.

Data Elements

The STS Adult Cardiac Surgery Database is a clinical database widely used to assess current clinical practice and outcomes. During the study period, STS data definitions and elements changed. For the present study, 4 versions of the STS data collection form were used: version 2.35 for 2000 to 2002, version 2.41 for 2002 to 2004, version 2.52 for 2004 to 2007, and version 2.61 for 2008 to 2009. Two versions were in use simultaneously during parts of 2002 and 2004. The definitions for these versions of the STS database can be found on the STS website.⁶ All definitions were reviewed by us to determine whether the study variables had comparable definitions over time. The variables that changed substantially were excluded from the analysis or were analyzed within shorter periods, during which the definitions were consistent. The variables that were analyzed during shorter periods have been appropriately labeled in the tabular data. Variables that had minor definitional changes were still used for the analysis. These variables included a history of cerebrovascular accident, preoperative arrhythmia, procedure status, and preoperative medications. The minor definitional changes have been described in detail in our previous study of isolated CABG.⁴

Study Endpoints

The study endpoints included operative mortality, stroke, renal failure, prolonged ventilation, deep sternal wound infection, reoperation for bleeding, new postoperative atrial fibrillation, and prolonged length of stay. Operative mortality was defined as death during the same hospitalization as the surgery or after discharge but within 30 days postoperatively. Stroke was defined as a central neurologic deficit persisting postoperatively for longer than 72 hours (database versions 2.35, 2.41, and 2.52) or longer than 24 hours (database version 2.61). Renal failure was defined as the development of a creatinine level greater than 2.0 mg/dL or twice the baseline level. Prolonged ventilation was defined as pulmonary insufficiency requiring mechanical ventilation for longer than 24 hours postoperatively. Deep sternal wound infection was defined as a sternal wound with positive wound culture findings that required antibiotics and incision and drainage.

Reoperation for bleeding was defined as an operative reintervention for bleeding or tamponade. A prolonged length of stay was defined as a postoperative hospital stay longer than 14 days.

Statistical Analysis

The statistical analysis has been described in detail in our previous study of isolated CABG.⁴ The summary statistics of patient characteristics and outcomes are presented as the frequency and percentage or median and interquartile range. Differences in patient characteristics across all study years were assessed using the chi-square test for categorical variables and the Wilcoxon rank sum test for continuous variables, with both tests stratified by STS participant identity. Given the large sample size, *P* values were not reported because practically every difference would have been statistically significant but not necessarily clinically significant. Logistic regression modeling was used to estimate the probability of mortality, stroke, reoperation for bleeding, and prolonged ventilation. We used the general estimated equation to account for participant variation. Explanatory variables included age, gender, body surface area, ejection fraction, dialysis, preoperative atrial fibrillation, shock, immune suppressive treatment, percutaneous coronary intervention (PCI) within 6 hours, preoperative intra-aortic balloon pump (IABP) or inotrope use, peripheral vascular disease, unstable angina (no myocardial infarction <7 days), left main disease, cerebrovascular disease, cerebrovascular accident, diabetes, number of diseased vessels, myocardial infarction status, congestive heart failure/New York Heart Association class, chronic lung disease, and interaction between gender and body surface area. The risk-adjusted outcomes were calculated by multiplying the year specifically observed to the expected ratio and the outcomes during the study period. To calculate the statistics of the observed, adjusted outcomes and the relative risk change, we treated the observed and adjusted outcomes as a binomial distribution and the expected outcomes as constants.

RESULTS

Study Population

From 2000 to 2009, 72,322 patients underwent isolated reoperative CABG at 1035 STS Adult Cardiac Surgery Database-participating institutions in the United States. During the same period 1,497,254 patients underwent isolated primary CABG. Overall, reoperative CABG constituted 4.8% (72,322/1,497,254) of the total surgical coronary revascularization experience.

Figure 1 illustrates the trends in CABG surgery during the past decade. As a percentage of overall CABG volume, reoperative CABG decreased from 6.0% (8820 reoperations vs 137,267 primary; 371 sites) in 2000 to 3.4% (5734 reoperations vs 160,997 primary; 978 sites) in 2009; a 35% reduction in reoperative CABG volume from 2000 to 2009.

Patient Risk Profile

The demographics and risk profiles of patients who underwent primary and reoperative CABG from 2000 to 2009 are compared in Table 1. The primary CABG data have been previously published but have been included in the present report to facilitate comparison.⁴ During the study period, no significant change occurred in age or gender in the reoperation CABG patients. Racial diversity increased, with fewer white patients in 2009 compared with 2000 (89% vs 95%). Patient weight (88 vs 84 kg) and body surface area (2.02 vs 1.98) increased. Medical

FIGURE 1. Incidence of reoperative coronary artery bypass grafting (CABG) during study period.

comorbidities, such as diabetes (42.5% vs 31.7%), hypercholesterolemia (93.0% vs 71.8%), renal failure (2.2% vs 0.7%), chronic obstructive pulmonary disease (25.5% vs 16.6%), hypertension (90.9% vs 73.4%), and cerebrovascular disease (12.4% vs 8.5%), were all more prevalent in 2009 than in 2000. No change was seen in the prevalence of peripheral vascular disease. A notable decrease has occurred in smoking from 61.9% of patients in 2000 to 21.6% of patients in 2009.

In 2009, the patients more often presented with congestive heart failure (18.4% vs 14.2%), left main disease (35.1% vs 25.7%), and myocardial infarction (60.9% vs 55.9%) and had more often undergone previous PCI (51% vs 35%). In 2009, reoperative CABG was more likely to be an urgent procedure than elective (51.6% vs 39%). In 2009, more patients were given preoperative β -blockers, angiotensin-converting enzyme (ACE) inhibitors, and statin medications.

The characteristics of the patients undergoing primary versus reoperative CABG are also listed in Table 1. In 2009, compared with primary isolated CABG, the reoperative CABG patients were older (67 vs 65 years), more commonly men (78.3% vs 72.9%), and more often had diabetes (42.5% vs 40.4%), hypercholesterolemia (93.0% vs 83.8%), chronic obstructive pulmonary disease (25.5% vs 22.7%), hypertension (90.9% vs 85.0%), peripheral vascular disease (22.5% vs 14.7%), and preoperative arrhythmia (13.0% vs 8.6%). Reoperative CABG patients also presented more often with left main disease (35.1% vs 31.6%), heart failure (18.4% vs 15.9%), and a lower ejection fraction (50% vs 55%).

Reoperative CABG Operative Characteristics

The operative characteristics between 2000 and 2009 are compared in Table 2. An increased prevalence was seen for

off-pump reoperative CABG (18% vs 12%) and a decrease in the use of internal thoracic artery grafting in reoperative CABG (40% vs 51%) in 2009. The cardiopulmonary bypass (112 vs 119 minutes) and crossclamp (72 vs 75 minutes) times decreased. A decrease was also seen in the use of preoperative, intraoperative, and postoperative IABP.

The operative characteristics of the patients undergoing primary and reoperative CABG are also listed in Table 2. In 2009, the use of the internal mammary artery (IMA) was markedly lower (39.5% vs 94.7%) in the reoperative CABG patients than in the primary CABG patients. Fewer procedures were performed off-pump (17.8% vs 21.1%), with longer perfusion (112 vs 89 minutes) and crossclamp (72 vs 52 minutes) times. Reoperative CABG patients more often required IABP placement in the intraoperative period (6.6% vs 1.5%) than did primary CABG patients.

Morbidity and Mortality

The postoperative observed mortality decreased from 6.1% (542/8820) in 2000 to 4.6% (261/5734) in 2009. The risk-adjusted mortality decreased from 6.0% to 4.7%. Figure 2 illustrates the observed, predicted, and adjusted postoperative mortality for each year during the study period. A 23.7% reduction occurred in the relative risk of mortality after reoperative CABG during the study period (Table 3). Figure 3 illustrates the observed, predicted, and adjusted postoperative stroke rates for each year during the study period. The observed stroke rate decreased from 1.9% to 1.4%. The risk-adjusted stroke rate decreased from 1.9% to 1.6%, with a 16.5% relative risk reduction for stroke. Other complications, such as renal failure (5.5% vs 4.7%) and deep sternal wound infection (0.7% vs 0.3%), also decreased during the study period. No change occurred in the incidence of reoperation for

TABLE 1. Preoperative patient profiles

Variable	Primary CABG		Reoperative CABG	
	2000 (n = 136,513)	2009 (n = 160,997)	2000 (n = 8784)	2009 (n = 5734)
Demographics and risk factors				
Age	65 (57-73)	65 (57-73)*	68 (61-74)	67 (61-74)*
Male gender	70.6%	72.9%*	79.5%	78.3%*
White race	92.0%	85.0%	95%	89%
Weight (kg)	84 (73-95)	86 (75-100)	84 (74-95)	88 (76 -100)
BSA	1.97 (1.81-2.12)	2.00 (1.84-2.16)	1.98 (1.84-2.11)	2.02 (1.87-2.17)
Smoker	59.5%	28.0%	61.9%	21.6%
Diabetes	33.4%	40.4%	31.7%	42.5%
Hypercholesterolemia	60.4%	83.8%	71.8%	93.0%
Renal failure with dialysis	1.2%	2.5%	0.7%	2.2%
COPD	16.9%	22.7%	16.6%	25.5%
Hypertension	70.9%	85.0%	73.4%	90.9%
Peripheral vascular disease	14.9%	14.7%*	20.7%	22.5%*
CHF	13.0%	15.9%	14.2%	18.4%
Cerebrovascular disease	5.9%	7.4%	8.5%	12.4%
Arrhythmia	10.0%	8.6%	12.3%	13.0%*
Left main disease	22.6%	31.6%	25.7%	35.1%
Ejection fraction	50 (40-60)	55 (45-60)	50 (40-57)	50 (40-60)
Myocardial infarction	45.4%	46.6%	55.9%	60.9%
Procedure status				
Elective	57.6%	41.3%	61%	48.4%
Urgent	38.0%	54.1%	35.8%	48.7%
Emergent	4.2%	4.4%	2.9%	2.9%
Emergent salvage	0.2%	0.2%	0.3%	0.1%
Previous interventions				
Preoperative PCI (with or without stent) <6 h	0.8%	0.9%*	1.2%	1.2%*
Any previous PCI (with or without stent)	19.1%	25.6%	35.4%	51.2%
Previous valve surgery	0.2%	0.2%	2.6%	3.5%
Previous other cardiac surgery	1.8%	1.4%	5.3%	4.0%
Preoperative medications				
Aspirin	73.1%	79.4%*	77.4%	78.9%*
β Blockers	61.9%	81.4%	66.2%	85.7%
ACE inhibitors†	38.4%	46.2%	44.1%	51.3%
Statin‡	60.6%	64.4%	68.8%	74.2%

Data presented as median (interquartile range) or n (%). CABG, Coronary artery bypass grafting; BSA, body surface area; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; PCI, percutaneous coronary intervention; ACE, angiotensin-converting enzyme. *Not statistically significant change. †Data from 2004, not 2000. ‡Data from 2005, not 2000 (primary CABG data published previously).⁴

bleeding, atrial fibrillation, prolonged ventilation, or prolonged length of stay.

The outcomes of primary versus reoperative CABG are also listed in Table 3. The mortality for reoperative CABG was 3.5 times that of primary CABG. In addition, reoperative CABG was associated with increased stroke (1.9% vs 1.2%), renal failure (5.5% vs 3.2%), reoperation for bleeding (2.9% vs 2.2%), and deep sternal wound infection (0.7% vs 0.4%).

DISCUSSION

The present study of 72,431 isolated reoperative and 1,497,254 primary CABG patients has identified a number of important changes in clinical practice during the past decade and has defined the contemporary clinical outcomes

from a large national database. The key finding of the present study was that isolated reoperative CABG is now an uncommon procedure performed in patients with more complex disease but with significant improvements in morbidity and mortality during the past decade. The overall mortality for reoperative CABG, however, remains markedly greater (3.5 times) than that for primary CABG. This increased mortality is likely secondary to the increased comorbidities and greater operative complexity of reoperative CABG patients.

Decline in Reoperative CABG Patient Volume

We have documented a progressive decline in the frequency of reoperative CABG in the practice of surgical coronary revascularization. Reoperative CABG is now an uncommonly performed operation. As a percentage of the

TABLE 2. Operative characteristics

Operative characteristics	Primary CABG		Reoperative CABG	
	2000 (n = 136,513)	2009 (n = 160,997)	2000 (n = 8784)	2009 (n = 5734)
Use of IMA	87.7%	94.7%	50.5%	39.5%
Off-pump procedure	14.5%	21.1%	12.2%	17.8%
Perfusion time	92 (72 -116)	89 (69 -113)	119 (92-152)	112 (85-144)
Per distal anastomosis	26 (19-31)	23 (18-30)	31 (24-40)	29 (22-38)
Crossclamp time (min)	61 (45-81)	52 (46-82)	75 (55-99)	72 (52-94)
Per distal anastomosis	17 (12-21)	16 (12-22)	19 (14-26)	18 (13-24)
Distal anastomoses (n)				
1	4.7%	4.5%	14.3%	16.9%
2	21.1%	20.5%	22.4%	32.3%
3	73.8%	74.7%	61.0%	50.5%
IABP use				
None	91.1%	90.1%	83.3%	85.7%
Preoperative	6.7%	8.1%	7.7%	6.9%
Intraoperative	1.6%	1.5%	7.1%	6.6%
Postoperative	0.4%	0.3%	1.7%	0.8%

Data presented as median (interquartile range) or n (%). CABG, Coronary artery bypass grafting; IMA, internal mammary artery; IABP, intra-aortic balloon pump.

overall CABG volume, reoperative CABG decreased from 6.0% in 2000 to 3.4% in 2009. Analyzed on a per center basis, reoperative CABG decreased from 24 cases/center in 2000 to 6 cases/center in 2009. This decrease has also been noted in other previous single-center studies.^{7,8} Spiliotopoulos and colleagues⁷ found that reoperative CABG decreased from 7.2% to just 2.2% of the overall CABG volume from 1990 to 2009 at the Toronto General Hospital. Similarly, Sabik and colleagues⁸ found that the reoperative CABG volume decreased by 50% at the Cleveland Clinic from 1990 to 2002.

The reason for the decline in reoperative CABG volume is unknown; however, we can speculate that improved medical management, expanded usage of PCI for native and saphenous vein graft disease, and increased arterial grafting at the initial CABG have all likely played a role. Improved medical therapy with increased use of β -blockers, statins,

and ACE inhibitors can slow the progression of coronary disease and delay or obviate the need for surgical revascularization.⁹ In the present study, among patients undergoing reoperative CABG, more were receiving statin and ACE inhibitor therapy in 2009 than in 2004. The emphasis on medical therapy rather than revascularization has also increased for patients with stable angina, which could have affected both the PCI and CABG volume.¹⁰ Riley and colleagues¹¹ found that PCI usage expanded by 31% from 2001 to 2004 in the US Medicare population. Since 2004, however, PCI use actually decreased by 20%, likely reflecting clinical trials demonstrating the lack of benefit to adding PCI to optimal medical therapy for stable coronary artery disease.¹⁰ The expanded role of PCI in the treatment of native and saphenous vein graft disease has likely also contributed to the reduced reoperative CABG volume.¹² In the present study, we noted that more patients undergoing reoperative

FIGURE 2. Mortality rate during study period for patients undergoing reoperative coronary artery bypass grafting (CABG).

TABLE 3. Postoperative mortality and morbidity

Variable	Primary CABG				Reoperative CABG			
	2000	2009	P value	Relative risk change	2000	2009	P value	Relative risk change
Mortality								
Observed	2.4%	1.9	<.001	−24.4% (−28.7% to −20.1%)	6.1%	4.6%	<.001	−25.9% (−37.9% to −13.9%)
Predicted	2.3%	2.3%			5.3%	5.2%		
Adjusted	2.3%	1.7%	<.001	−22.8% (−27.3% to −18.3%)	6.0%	4.6%	<.001	−23.7% (−35.9% to −11.5%)
Stroke								
Observed	1.6%	1.2%	<.001	−26.4% (−31.6% to −21.1%)	1.9%	1.4%	<.001	−22.0% (−44.5% to 0.6%)
Predicted	1.3%	1.3%			1.6%	1.5%		
Adjusted	1.6%	1.2%	<.001	−26.4% (−31.6% to −21.2%)	1.9%	1.6%	<.001	−16.5% (−39.4% to 6.4%)
Renal failure								
Observed	3.5%	3.6%	.005	5.5% (1.6% to 9.3%)	5.5%	4.7%	<.008	−14.7% (−28.0% to −1.5%)
Predicted	3.8%	4.0%			5.4%	5.4%		
Adjusted	3.2%	3.2%	.956	−0.1% (−4.1% to 3.9%)	5.5%	4.9%	<.004	−15.4% (−28.5% to −2.3%)
Reoperation for bleeding								
Observed	2.5%	2.2%	<.001	−9.2% (−13.6% to −4.7%)	2.9%	3.6%	.291	22.1% (1.7% to 42.6%)
Predicted	2.5%	2.4%			3.2%	3.1%		
Adjusted	2.4%	2.2%	.002	−7.1% (−11.6% to −2.5%)	2.9%	3.7%	.085	27.6% (6.8% to 48.5%)
Deep sternal wound infection								
Observed	0.6%	0.4%	<.001	−32.9% (−41.8% to −23.9%)	0.6%	0.3%	<.001	−57.7% (−24.8% to −90.7%)
Predicted	0.4%	0.4%			0.5%	0.5%		
Adjusted	0.6%	0.4%	<.001	−37.3% (−45.8% to −28.7%)	0.7%	0.3%	<.001	−59.3% (−27.4% to −91.2%)
Atrial fibrillation								
Observed	19.8%	21.1%	<.001	6.4% (4.9% to 7.8%)	18.7%	19.8%	.396	6.3% (−1.0% to 13.6%)
Predicted	20.3%	21.2%			19.2%	19.5%		
Adjusted	20.0%	20.5%	.004	2.2% (0.7% to 3.6%)	19.0%	19.9%	.532	4.8% (−2.4% to 12.0%)
Prolonged ventilation								
Observed	7.6%	10.7%	<.01	40.0% (37.3% to 42.7%)	11.9%	16.6%	.396	39.6% (29.8% to 49.5%)
Predicted	11.2%	12.0%			14.9%	15.8%		
Adjusted	6.5%	8.5%	<.001	31.2% (28.3% to 34.1%)	11.6%	15.3%	.532	31.4% (22.5% to 41.2%)
Prolonged LOS								
Observed	5.0%	5.2%	<.01	4.8% (1.7% to 8.0%)	7.5%	7.3%	.977	−2.9% (−14.5% to 8.7%)
Predicted	5.9%	6.1%			7.4%	7.8%		
Adjusted	4.5%	4.6%	<.01	0.8% (−2.5% to 4.1%)	7.8%	7.1%	.203	−8.5% (−19.7% to 2.7%)

CABG, Coronary artery bypass grafting; LOS, length of stay.

CABG had previously been treated with PCI (an increase from 35% of patients in 2000 to 53% of patients in 2009). During the past 2 decades, an increased use of arterial grafts has occurred during initial CABG.⁴ The increased use of the IMA and other arterial grafts might have led to improved graft patency and a decreased need for repeat CABG.^{13,14} Improved postoperative medical management after initial revascularization could also have improved the freedom from reoperation.¹⁵

Given the significant decline in reoperative CABG surgery (only 6 cases/center), individual surgeon experience with CABG is becoming limited. Referral to higher volume surgeons or centers might be prudent for complex reoperative coronary revascularization.

Evolving Patient Risk Profile and Operative Practice

Both primary and reoperative CABG risk profiles have changed from 2000 to 2009. The primary CABG patient risk profiles have been described in our previous study.⁴

Although many surgeons have perceived that their patients are older, we surprisingly found no statistically significant change in patient age or gender. The prevalence of a number of comorbidities was significantly greater in 2009 than in 2000. In general, when analyzing large clinical databases, one must distinguish clinically significant changes from statistically significant changes. The increased prevalence of diabetes, hypercholesterolemia, renal failure, chronic obstructive pulmonary disease, and hypertension have all been substantial and, we believe, of clinical significance. Patients now weigh 5% (4 kg) more and have a greater body surface area. Also, a clinically significant greater incidence was seen for left main disease, myocardial infarction, congestive heart failure, and the need for urgent or emergent operations. However, an impressive decrease has occurred in smoking prevalence from 62% in 2000 to 22% in 2009. Taking into account all these data, we believe that reoperative CABG patients now present with significantly more comorbidities and more complex coronary artery disease.

FIGURE 3. Stroke rate during study period for patients undergoing reoperative coronary artery bypass grafting (CABG).

The operative practice for primary and reoperative CABG patients has also evolved significantly. An increase has occurred in the use of off-pump procedures. Although IMA graft use has increased in primary CABG, it has decreased in reoperative CABG. We hypothesized that this decrease in IMA use in reoperative CABG is linked to the increased IMA use in primary CABG. Because previous bypass graft data for reoperative CABG were not included in the STS database, this hypothesis could not be evaluated. The modest improvements in perfusion and crossclamp times and decrease in IABP use might not have been large enough to result in a clinically significant change.

Contemporary Mortality and Morbidity

Despite patients with more complex disease, the operative mortality and morbidity have significantly improved from 2000 to 2009. In the present study, the current risk-adjusted operative mortality for isolated reoperative CABG was 4.6%, representing an adjusted relative risk reduction of operative mortality of 23.7% during the decade. Previous studies have reported operative mortality for reoperative CABG ranging from 4.8% to 16.7%.¹⁶ More recent studies have also shown that the operative mortality has significantly improved.^{7,8} These results mirror the improvements in operative mortality for primary isolated CABG, for which we found that the unadjusted operative mortality had improved from 2.4% to 1.9% during the same period.⁴

The operative morbidity has also significantly decreased. Postoperative stroke occurred in 1.4% of patients in the current era, representing a 16.5% adjusted relative risk reduction during the past decade. Similarly, in our study of isolated primary CABG, we found a stroke rate of 1.2%.⁴ Tarakji and colleagues¹⁷ evaluated the stroke rate for 45,000 patients who underwent CABG at the Cleveland

Clinic and similarly found that the stroke rate decreased from 2.6% in 1988 to 1.6% in 2009. In addition, that study noted decreases in the rate of renal failure and deep sternal wound infection.

Improvements in Pre-, Intra-, and Postoperative Management

We believe the improvements in operative mortality and morbidity during the past decade resulted from a variety of improvements in the pre-, intra-, and postoperative management for patients undergoing reoperative CABG.

In addition to better preoperative medical management, better preoperative planning using imaging techniques has likely improved the operative outcomes. Preoperative imaging using computed tomography assists with operative planning for sternal re-entry, preservation of previous graft conduits, and cannulation strategies.^{18,19} Myocardial viability studies can help identify appropriate targets for revascularization.²⁰

A number of improvements have been made in intraoperative management and cardiac anesthesia. The increased use of intraoperative transesophageal echocardiography and epiaortic scanning might reduce the incidence of stroke and guide placement of retrograde cardioplegia, peripheral cannulation, and IABP.^{21,22} Adequate myocardial protection during reoperative CABG can be challenging, particularly in the setting of a patent mammary graft. The increased use of retrograde cardioplegia and systemic hyperkalemia aid in achieving diastolic arrest and myocardial protection.^{23,24}

A number of improvements has occurred in postoperative management, including the development of dedicated cardiothoracic intensivists, early extubation protocols, blood conservation, and glucose control.^{25,26}

Comparison With Primary CABG

Despite the improvements, reoperative CABG has greater risks of operative mortality and morbidity compared with primary CABG. This is not surprising, given that reoperative CABG is performed in older, sicker patients and involves greater technical complexity, with sternal re-entry, peripheral cannulation, conduit availability, and poor target vessels. These technical challenges lead to prolonged bypass and crossclamp times compared with those for primary CABG. In addition, patients who require reoperative CABG likely have more diffuse and earlier onset disease than do primary CABG patients. These multiple factors are likely the reason for the 3.5 times increased mortality risk in reoperative CABG patients.

Given this increased mortality risk, efforts to avoid requiring reoperative CABG should continue. More arterial grafting and continued improvements in medical management (eg, aspirin, β -blockers, statins) should be emphasized. Planning for the second operation should begin at the primary operation to reduce later mortality and morbidity risk should the patient require a reoperation. Conduits should be positioned to allow safe sternal re-entry (eg, appropriate localization of the IMA under the upper lobe and away from the midline). Loose pericardial closure should also be considered, when feasible.

Study Limitations

The present study was limited to the information provided in the STS Adult Cardiac Surgery Database. Because this database currently represents 978 institutions performing cardiac surgery in the United States, the results of this database are reflective of current clinical practice and generalizable to the general population. As described in the “Materials and Methods” section, some database definition changes occurred during the course of the present study. These changes were minor, and we believe did not affect the validity of our findings. The STS database is limited only to perioperative outcomes; thus, we could not draw any conclusions about the long-term postoperative outcomes. The database does not contain information regarding the indication for reoperative CABG (eg, progression of native disease, failed vein graft, failed PCI). We noted a decrease in the use of internal thoracic arterial grafting in reoperative CABG and hypothesized that was resulted from an increased use of thoracic arterial grafting at primary CABG. Because the STS database does not capture the conduits used in previous CABG, we could not evaluate this hypothesis in the present study. Before July 2011, the database did not capture the interval between the current and previous operation.

CONCLUSIONS

A decrease has occurred in reoperative CABG surgery volume in the United States during the past decade. The patients who do undergo reoperative CABG have more

complex coronary artery disease and a greater incidence of medical comorbidities but have improved preoperative medical management with an increased use of statin and ACE inhibitor therapy. The operative morbidity and mortality have also significantly improved. Reoperative CABG surgery is now performed with an operative mortality of 4.6% and stroke rate of 1.4% in the United States. These outcomes should serve as benchmarks for competing revascularization therapies for patients who have previously undergone cardiac surgery.

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