Does grafting coronary arteries with only moderate stenosis affect long-term mortality?

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ABSTRACT

Objective: Stenting coronary arteries with non-ischemia-producing moderate stenosis leads to worse outcomes than leaving them unstented. We sought to determine whether grafting coronary arteries with angiographically moderate stenosis is associated with worse long-term survival than leaving them ungrafted.

Methods: From 1972 to 2011, 55,567 patients underwent primary isolated coronary artery bypass grafting (CABG); 8531 had a single coronary artery with moderate (50%-69%) stenosis, bypassed in 6598 (77%) and not bypassed in 1933 (23%). These arteries were grafted with internal thoracic arteries (ITAs) in 1806 patients (27%) and with saphenous veins (SVs) in 4625 (70%). Mean follow-up for all-cause mortality was 13.0 ± 9.7 years.

Results: Survival was similar for patients with and without a graft to the moderately stenosed coronary artery ($P = .3$): 97%, 76%, 43%, and 18% at 1, 10, 20, and 30 years among patients receiving no graft; 97%, 74%, 41%, and 18% among those receiving an SV graft; and 98%, 82%, 51%, and 23% among those receiving an ITA graft. After adjusting for patient characteristics, SV grafting versus nongrafting of moderately stenosed coronary arteries was associated with similar long-term mortality ($P = .2$), whereas ITA grafting was associated with 22% lower long-term mortality (hazard ratio 0.78; 68% confidence interval 0.75-0.82; $P < .0001$).

Conclusions: Grafting coronary arteries with angiographically moderate stenosis is not harmful. Instead, ITA grafting of such coronary arteries is associated with lower long-term mortality. Thus, after placing the first ITA to the left anterior descending, the second ITA should be placed to the second most important coronary artery, even if it is moderately stenosed. (J Thorac Cardiovasc Surg 2016;151:806-11)

Survival after ITA versus SV grafting versus no grafting of moderately stenosed coronary arteries.

Central Message

Grafting moderately stenosed coronary arteries is not harmful. Internal thoracic artery grafting of such arteries is associated with lower late mortality.

Perspective

Internal thoracic artery (ITA) grafting of coronary arteries with angiographically moderate stenosis is associated with lower long-term mortality. Therefore, after placing the first ITA to the left anterior descending coronary artery, the second ITA should be used to graft the next most important coronary artery, even if it is only moderately stenosed.

See Editorial Commentary page 812.

See Editorial page 300 in the February issue.

Stenting coronary arteries with non-ischemia-producing moderate stenosis leads to worse outcomes than leaving them unstented.¹⁻³ Although an ischemia-guided approach yields better percutaneous coronary intervention (PCI)

outcomes than the traditional angiographically guided approach,¹⁻³ its value in patients undergoing coronary artery bypass grafting (CABG) is unknown. Most angiographically moderate coronary stenoses would not

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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CAD	= coronary artery disease
CL	= confidence limit
FFR	= fractional flow reserve
ITA	= internal thoracic artery
IVUS	= intravascular ultrasound
LAD	= left anterior descending coronary artery
LCx	= left circumflex coronary artery
PCI	= percutaneous coronary intervention
RCA	= right coronary artery
SV	= saphenous vein

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be identified by an ischemia-guided approach as candidates for revascularization, yet traditionally, surgeons have attempted to bypass all such lesions. Therefore, we sought to determine whether grafting coronary arteries with moderate anatomic stenosis is associated with poorer long-term mortality than leaving them ungrafted.

PATIENTS AND METHODS

From 1972 to 2011, 55,567 patients underwent primary isolated CABG at Cleveland Clinic. Of these, 8531 had a single coronary artery with angiographically moderate (50%-69%) stenosis as defined by expert cardiologists, bypassed in 6598 patients (77%) and not bypassed in 1933 (23%). These patients had bypasses to all other coronary arteries with severe ($\geq 70\%$) stenoses. Moderate stenosis was present in the circumflex artery in 2714 patients (32%), right coronary artery (RCA) in 2599 (30%), diagonals in 1635 (19%), and left anterior descending coronary artery (LAD) in 1583 (19%; [Table 1](#)). Internal thoracic arteries (ITA) were used to graft moderately stenosed coronary arteries in 1806 patients (27%), and saphenous vein (SV) grafts were used in 4625 (70%). Most ITA grafts went to the LAD, followed by diagonals and the left circumflex (LCx) coronary artery, and most SV grafts went to the RCA, followed by the LCx and diagonals ([Table E1](#)).

Patients with multiple systems of moderate stenosis, left main disease with $\geq 50\%$ stenosis, any bypassed lesion with $< 50\%$ stenosis, incomplete revascularization of coronary systems with $\geq 70\%$ stenosis, or previous PCI were excluded from the study. Our rationale for this study design was that if multiple moderately stenosed arteries were present, the analysis would be confounded, particularly if each moderately stenosed lesion was managed differently, as also would be the case if severely stenosed coronary arteries were not grafted. Thus, we studied a single moderately stenosed coronary artery in isolation of these confounding factors.

Patients were identified and preoperative, operative, and postoperative variables ([Appendix E1](#)) retrieved from the prospective Cleveland Clinic Cardiovascular Information Registry. This database is populated

concurrently with patient care and has been approved for use in research by the Cleveland Clinic Institutional Review Board, with patient consent waived.

Endpoint

The endpoint of this study was long-term mortality. Vital status after hospital discharge was obtained by routine anniversary follow-up questionnaires supplemented with data from the Social Security Death Master File,^{4,5} accessed on October 27, 2011, with a closing date of April 27, 2011. A total of 112,051 patient-years of follow-up data were available for analyses. Mean follow-up was 13 ± 9.7 years (median, 12 years), with 25% of survivors followed for more than 22 years and 10% for more than 29 years.

Data Analysis

Long-term survival. Survival was assessed nonparametrically by using the Kaplan-Meier method⁶ and parametrically by using a multiphase hazard model.⁷ The latter involved resolving the number of hazard phases for instantaneous risk of death (hazard function) and estimating shaping parameters (for details, see www.lerner.ccf.org/qhs/software/hazard). Survival estimates with associated 68% confidence limits (CLs) were plotted for selected time points for the bypass groups and by location of moderate stenosis.

Risk adjustment. Multivariable analysis was performed in the hazard function domain by using the parametric multiphase hazard model, with factors modulating both hazard phases considered simultaneously.

Variables considered in the analysis are listed in [Appendix E1](#). Variable selection, with a *P*-value criterion for retention of variables in the model of .05, used the machine-learning “bagging” method (bootstrap aggregation)^{8,9} with automated stepwise variable selection for 500 bootstrap data sets, followed by assessment of the frequency of occurrence of variables in these models. Those appearing in 50% or more of the models were retained in the final model. Variables related to management of the moderate coronary artery disease (CAD) were examined closely. Although none of these met the 50% reliability criterion for variable selection, we forced into the model the type of graft and whether the moderate systems were bypassed or not.

Missing values. A number of variables examined in multivariable analyses had missing values. We used fivefold multiple imputation¹⁰ with a Markov chain Monte Carlo technique to impute missing values (SAS PROC MI; SAS Institute, Cary, NC). In multivariable modeling, for each imputed complete data set, we estimated regression coefficients and their variance–covariance matrix. Then, following Rubin,¹⁰ we combined estimates from the 5 models (SAS PROC MIANALYZE) to yield final regression coefficient estimates, the variance–covariance matrix, and *P* values.

Presentation. Categorical data are summarized by frequencies and percentages; comparisons were made using the χ^2 test or Fisher’s exact test when frequency was less than 5. Continuous variables are summarized as mean $\pm$ standard deviation, or as 15th, 50th (median), and 85th percentiles when data are skewed; comparisons were made using the Wilcoxon rank-sum test. Uncertainty is expressed by CLs equivalent to ± 1 standard error (68%). All analyses were performed using SAS statistical software (SAS version 9.2).

RESULTS

Patient Characteristics

Most baseline patient characteristics were similar in patients with grafted moderately stenosed coronary arteries and those with nongrafted moderately stenosed coronary

TABLE 1. Patient characteristics stratified by nongrafted versus grafted moderate CAD

Characteristic	Not grafted, n = 1933		Grafted, n = 6598		P
	n*	No. (%) or mean $\pm$ SD	n*	No. (%) or mean $\pm$ SD	
Demography					
Age, y	1933	59 $\pm$ 10	6598	60 $\pm$ 10	<.0001
Female	1933	350 (18)	6598	1299 (20)	.12
Race					
Black	1669	46 (2.8)	6401	97 (3.1)	.5
White	1669	1536 (92)	6401	5876 (92)	.8
Body mass index, kg·m ⁻²	942	28 $\pm$ 4.8	4360	28 $\pm$ 4.6	.06
Symptoms					
NYHA functional class	1923		6587		<.0001
I		285 (15)		1267 (19)	
II		705 (37)		2506 (38)	
III		225 (12)		675 (10)	
IV		708 (37)		2139 (32)	
Emergency operation	1933	31 (1.6)	6598	49 (0.74)	.0006
Cardiac comorbidities					
Prior myocardial infarction	1933	917 (47)	6598	3244 (49)	.18
Atrial fibrillation or flutter	1442	16 (1.1)	5458	71 (1.3)	.6
Heart failure	1933	113 (5.8)	6598	331 (5.0)	.15
Noncardiac comorbidities					
History of smoking	1829	971 (53)	6423	3371 (52)	.6
Stroke	1933	61 (3.2)	6598	296 (4.5)	.01
Carotid artery disease	1933	158 (8.2)	6598	572 (8.7)	.5
Peripheral vascular disease	1933	190 (9.8)	6598	640 (9.7)	.9
Pharmacologically treated diabetes	1851	330 (18)	6321	1149 (18)	.7
Bilirubin, mg·dL ⁻¹	526	0.69 $\pm$ 1.01	2294	0.62 $\pm$ 0.41	.7
Creatinine, mg·dL ⁻¹	588	1.2 $\pm$ 0.71	2547	1.2 $\pm$ 0.89	.4
Blood urea nitrogen, mg·dL ⁻¹	587	19 $\pm$ 8.5	2552	19 $\pm$ 10	.3
Cholesterol, mg·dL ⁻¹	1445	232 $\pm$ 59	5015	229 $\pm$ 55	.05
Triglycerides, mg·dL ⁻¹	1219	191 $\pm$ 122	4266	185 $\pm$ 128	.002
Hematocrit, %	543	39 $\pm$ 5.9	2354	40 $\pm$ 5.1	.02
Coronary anatomy					
No. of systems diseased†	1933		6598		<.0001
1		49 (2.5)		172 (2.6)	
2		606 (31)		1710 (26)	
3		1278 (66)		4716 (71)	
No. of systems diseased‡	1933		6598		<.0001
0		1 (0.05)		82 (1.2)	
1		503 (26)		1536 (23)	
2		1029 (53)		4298 (65)	
3		400 (21)		682 (10)	
Moderate CAD§					
In right coronary artery	1933	654 (34)	6598	1945 (29)	.0003
In left anterior descending	1933	121 (6.3)	6598	1462 (22)	<.0001
In left circumflex	1933	559 (29)	6598	2155 (33)	.002
In diagonal	1933	599 (31)	6598	1036 (16)	<.0001

SD, Standard deviation; NYHA, New York Heart Association; CAD, coronary artery disease. *Patients with data available. † $\geq$ 50% stenosis. ‡ $\geq$ 70% stenosis. §50%-69% stenosis.

arteries (Table 1). However, more patients in the nongrafted group had slightly higher triglyceride levels (191 $\pm$ 122 vs 185 $\pm$ 128) and underwent emergency operation (1.6% vs 0.74%), whereas more patients in the grafted group had 3-system CAD (71% vs 66%) than their nongrafted counterparts.

Survival

Survival was similar for patients with and without a graft to the moderately stenosed coronary artery ($P = .3$; Figure 1, A). Survival at 1, 5, 10, 20, and 30 years was 97%, 90%, 76%, 43%, and 18% in patients receiving no graft to moderately stenosed coronary arteries; 97%,

FIGURE 1. Unadjusted long-term survival in patients undergoing coronary artery bypass grafting (CABG) with 1 moderately stenosed artery (n = 8531). Curves are Kaplan-Meier estimates with associated 68% confidence limits (vertical bars). A, Stratified by grafted versus nongrafted artery. B, Stratified by internal thoracic artery (ITA) grafting versus saphenous vein (SV) grafting versus nongrafting of artery.

89%, 74%, 41%, and 18% in those receiving SV grafts; and 98%, 93%, 82%, 51%, and 23% in those receiving ITA grafts (Figure 1, B). Among the 5171 patients receiving an ITA graft to a severely stenosed LAD, long-term survival was better if the moderately stenosed non-LAD coronary was grafted with the second ITA instead of an SV graft or if no graft was used (Figure E1).

Risk-Adjusted Survival

After adjusting for patient characteristics, early mortality was similar for patients with and without a graft to a

moderately stenosed coronary artery ($P = .3$; Figure 2, A; Tables 2 and E2), but late mortality was 11% lower in patients with a graft to the moderately stenosed coronary artery ($P = .003$). SV grafting versus nongrafting of moderately stenosed coronary arteries was associated with similar early and late mortality (early $P = .8$; late $P = .2$), whereas ITA grafting versus nongrafting of such arteries was associated with 53% lower early mortality and 22% lower long-term mortality (early $P = .0001$; late $P < .0001$; Figure 2, B and Tables 3 and E3).

FIGURE 2. Adjusted long-term survival in patients undergoing coronary artery bypass grafting (CABG) with 1 moderately stenosed coronary artery. Solid lines are parametric estimates enclosed within 68% dashed confidence limits. Panel (A) is a nomogram of the multivariable equation in Table E1 and panel (B) is a nomogram of the multivariable equation in Table E2 for a patient with the following characteristics: age = 60 years, body mass index = $28 \text{ kg} \cdot \text{m}^{-2}$, weight = 80 kg, no previous stroke, no heart failure, no peripheral vascular disease, no history of smoking, no diabetes, no prior myocardial infarction, New York Heart Association functional class II, triglycerides = $180 \text{ mg} \cdot \text{dL}^{-1}$, number of internal thoracic artery grafts to vessel with severe stenosis ($\geq 70\%$) = 1, number of diseased coronary systems = 3. A, Stratified by grafting versus nongrafting of artery. B, Stratified by internal thoracic artery (ITA) grafting versus saphenous vein grafting (SVG) versus nongrafting of artery.

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TABLE 2. Effect of grafting versus nongrafting of moderately stenosed coronary arteries (n = 8531)

Factor	Coefficient ± SE	Hazard ratio (95% CLs)	P
Early phase*			
Moderate CAD bypassed	−0.128 ± 0.135	0.88 (0.67-1.15)	.3
Late phase*			
Moderate CAD bypassed	−0.114 ± 0.038	0.89 (0.83-0.96)	.003

Reference group: moderate CAD not grafted. *SE*, Standard error; *CL*, confidence limits; *CAD*, coronary artery disease. *After adjusting for age, body mass index, weight, New York Heart Association functional class, previous myocardial infarction, heart failure, elevated triglycerides, peripheral vascular disease, stroke, treated diabetes, history of smoking, number of coronary artery systems diseased, emergency operation, and internal thoracic artery grafting of coronary arteries with severe ($\geq 70\%$) stenosis (see Table E1).

DISCUSSION

Principal Findings

This study demonstrates that grafting coronary arteries with angiographically moderate stenosis was not harmful. SV grafting versus nongrafting of moderate lesions was associated with similar long-term survival, and ITA grafting of such lesions was associated with better long-term survival.

Findings in Context

Stenting coronary arteries with non–ischemia-producing moderate stenosis leads to worse outcomes than leaving them unstented.^{1,2} Our study shows that grafting coronary arteries with angiographically moderate stenosis is not harmful, whereas ITA grafting of such lesions is beneficial. The explanation for these contrasting findings between stenting and grafting may lie in the fundamental differences between revascularization achieved by PCI

TABLE 3. Effect of internal thoracic artery and saphenous vein grafting versus nongrafting of moderately stenosed coronary arteries (n = 8531)

Factor	Coefficient ± SE	Hazard ratio (95% CLs)	P
Early phase*			
ITA graft to moderate CAD	−0.76 ± 0.20	0.47 (0.32-0.69)	.0001
SV graft to moderate CAD	0.0088 ± 0.034	1.01 (0.94-1.08)	.8
Late phase*			
ITA graft to moderate CAD	−0.242 ± 0.051	0.78 (0.71-0.87)	<.0001
SV graft to moderate CAD	−0.047 ± 0.039	0.95 (0.88-1.03)	.2

Reference group: moderate CAD not grafted. *SE*, Standard error; *CL*, confidence limits; *ITA*, internal thoracic artery; *CAD*, coronary artery disease; *SV*, saphenous vein. *After adjusting for age, body mass index, weight, New York Heart Association functional class, previous myocardial infarction, heart failure, elevated triglycerides, peripheral vascular disease, stroke, treated diabetes, history of smoking, number of coronary artery systems diseased, emergency operation, and internal thoracic artery grafting of coronary arteries with severe ($\geq 70\%$) stenosis (see Table E2).

and revascularization achieved by CABG. First, thrombosis or early restenosis in a stent can lead to myocardial ischemia and infarction,¹ whereas grafting a moderate lesion may lead only to early graft closure with preserved antegrade blood flow from the patent coronary artery, resulting in no harm to the patient. Second, PCI treats lesions as they exist at the time of the procedure, relying in the long term on the coronary artery to remain patent distal to the stent. We know that beyond 1 year after stenting, new events result almost exclusively from the progression of disease in segments other than the stented lesion.¹¹ Compared with PCI, CABG brings a second source of blood flow to the distal coronary artery that, if it remains patent, is independent of possible proximal plaque rupture that may occur with time. It is important to note that moderate lesions tend to be the culprits because their acute thrombosis can lead to myocardial infarction.¹² Therefore, a patent graft to a moderately stenosed coronary artery might be protective in the long run. Hayward and colleagues¹³ showed that at 8 years, 83% of grafts to moderately stenosed left-sided lesions, and at 7 years, 73% of grafts to moderately stenosed right-sided lesions, remain patent. Therefore, in weighing the risks and benefits of grafting versus nongrafting of a moderate lesion, the balance lies in favor of grafting.

Studies from the 1970s of the natural history of CAD also showed that survival is better in patients with fewer coronary arteries with $\geq 50\%$ stenosis, demonstrating that 50% stenosis does influence survival.¹⁴ One reason patients are referred for CABG is that, traditionally, it has offered more complete revascularization than PCI. There is evidence that incomplete revascularization based on $\geq 50\%$ stenosis determined by angiography is associated with decreased long-term survival.^{15,16}

Grafting the LAD (irrespective of the degree of stenosis $\geq 50\%$) with an ITA is the gold standard of primary coronary surgery. Our study shows that grafting moderate lesions with an ITA is associated with better long-term survival than SV grafting or nongrafting. Given this, the most important clinical implication for surgeons that can be derived from the results of this study is that once the first ITA has been placed to the LAD, the second ITA should be used to graft the next most important coronary artery, which is usually the LCx, even if it is only moderately stenosed. Our previously published paper on competitive flow also showed that “Internal thoracic artery patency decreases as coronary competitive flow increases. However, the nature of this relationship indicates ITAs should not be abandoned at moderate grades of stenosis.”¹⁷

Ischemia-driven revascularization

In CABG, use of fractional flow reserve (FFR), which evaluates the potential of a coronary artery to induce myocardial ischemia, is rare. Studies evaluating FFR versus

angiographically guided CABG have few patients and a short follow-up of 3 years or less.¹⁸ Also, this technique of assessing the potential of a coronary artery to induce myocardial ischemia has limitations. The experimental basis of FFR assumes normal distal microcirculation¹⁹; however, this may not be true for patients with diffuse coronary disease or diabetes, who may have small-vessel disease distal to the tip of the pressure-measuring device, and this is the patient population mostly referred for surgery. The usefulness of FFR in the setting of bifurcation lesions and poor response to coronary vasodilators, such as patients with left ventricular hypertrophy, also requires further evaluation.²⁰

Limitations

First, this was an observational, nonrandomized, comparative effectiveness study, and patient factors might have influenced our findings. To account for this, we performed multivariable risk adjustment, but any patient factors not included in the analysis that could affect mortality might have biased our findings. Second, this was a single-center study, and findings may not be generalizable. Third, because 4 decades of data were used for analyses, applicability of these results to contemporary patients could be questioned. For this, we adjusted for the date of operation in our multivariable model. Fourth, in part we used the Social Security Death Master File for long-term follow-up, which provides only all-cause mortality. Therefore, we do not know whether deaths in our study were cardiac or noncardiac related. Fifth, we were unable to do separate subset analyses for each coronary system because the numbers were too small for meaningful comparisons. Sixth, we did not have coronary intravascular ultrasound (IVUS) or FFR data for the patients in the study. IVUS was not generally used to quantify stenosis, and FFR came into common use just recently. Seventh, our stenosis data are based on qualitative angiography and not quantitative angiography. Although quantitative coronary angiography is more reproducible, it is time-consuming and expensive. Given that we have more than 8500 patients in the study, retrospective quantitative analysis was not feasible. More importantly, clinical decision making is virtually always based on qualitative and not quantitative angiography. Therefore, qualitative angiography represents the real-world approach.

CONCLUSIONS

Grafting coronary arteries with angiographically moderate stenosis is not harmful. Instead, ITA grafting of such coronary arteries is associated with lower long-term mortality. Therefore, after placing the first ITA to the LAD, the second ITA should be placed to the second most important coronary artery, even if it is only moderately stenosed.

Conflict of Interest Statement

Dr Sabik is the North American principal investigator for the Abbott Laboratories–sponsored left main coronary disease randomized trial (EXCEL), is on the Society for Thoracic Surgeons board of directors, and is on the scientific advisory board of Medtronic. All other authors have nothing to disclose with regard to commercial support.

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Key Words: coronary artery, moderate stenosis, coronary artery bypass grafting, long-term survival, ischemia-guided approach, fractional flow reserve

APPENDIX E1. VARIABLES CONSIDERED IN MULTIVARIABLE ANALYSES

Demography

Age (y), sex, race (white, black, other), weight (kg), height (cm), weight/height ratio, body surface area (m^2), body mass index ($\text{kg} \cdot \text{m}^{-2}$)

Status/Symptoms

New York Heart Association functional class (I-IV), emergency operation

Cardiac comorbidity

Prior myocardial infarction, atrial fibrillation or flutter, heart failure

Noncardiac comorbidity

Treated diabetes, peripheral vascular disease, carotid disease, hypertension, history of smoking, prior stroke, cholesterol ($\text{mg} \cdot \text{dL}^{-1}$), triglycerides ($\text{mg} \cdot \text{dL}^{-1}$), creatinine ($\text{mg} \cdot \text{dL}^{-1}$)

Coronary anatomy

Number of coronary systems diseased ($\geq 50\%$ stenosis), left anterior descending (LAD) disease ($\geq 50\%$, moderate

[50%-69%], severe [$\geq 70\%$]), left circumflex (LCx) system disease ($\geq 50\%$, moderate [50%-69%], severe [$\geq 70\%$]), right coronary artery (RCA) system disease ($\geq 50\%$, moderate [50%-69%], severe [$\geq 70\%$]), diagonal (Dg) disease ($\geq 50\%$, moderate [50%-69%], severe [$\geq 70\%$]), location of moderate coronary artery disease (CAD; LAD, Dg, LCx, RCA)

Coronary Artery Bypass Grafting Procedures

Number of internal thoracic artery (ITA) grafts used to graft severely stenosed arteries (none, 1, 2), conduit used to bypass moderate CAD (none, ITA, saphenous vein, radial artery, other), graft locations (LAD, LAD diagonals, LCx territory, RCA territory), interaction terms for conduit used to bypass moderate CAD in each location (none, ITA, saphenous vein)

Support

Cardiopulmonary bypass (off-pump vs on-pump), bypass time (min)

Experience

Date of operation (years since January 1, 1972)

FIGURE E1. Survival advantage of internal thoracic artery (ITA) grafting of a moderately stenosed non-left anterior descending coronary artery (LAD) after ITA grafting of a severely stenosed LAD. Format is as in Figure 1. SVG, Saphenous vein graft; CABG, coronary artery bypass grafting.

TABLE E1. Conduits placed to each moderately stenosed coronary artery: No. (%)

	Overall, n = 8531	LAD, n = 1583	RCA, n = 2599	LCx, n = 2714	Diagonal, n = 1635
Not bypassed	1933 (23)	121 (7.6)	654 (25)	559 (21)	599 (37)
ITA graft	1806 (21)	1167 (74)	121 (4.7)	313 (11)	205 (12)
SV graft	4625 (54)	291 (18)	1774 (68)	1757 (65)	803 (49)
Other graft	167 (2.0)	4 (0.25)	50 (1.9)	85 (3.1)	28 (1.7)

LAD, Left anterior descending coronary artery; RCA, right coronary artery; LCx, left circumflex coronary artery; ITA, internal thoracic artery; SV, saphenous vein.

TABLE E2. Risk factors for mortality after CABG with 1 system of moderate CAD (n = 8531): reference group = moderate CAD grafted versus nongrafted

Factor	Estimate ± SE	P	Reliability, %*
Early phase			
Demography			
Older age†	0.462 ± 0.089	<.0001	68
Lower BMI‡	0.324 ± 0.104	.002	55
Status/symptoms			
Emergency operation	0.995 ± 0.331	.002	63
NYHA class II	−0.342 ± 0.136	.010	90
Comorbidities			
Peripheral vascular disease	0.669 ± 0.156	<.0001	72
Prior stroke	0.564 ± 0.213	.008	54
Heart failure	0.808 ± 0.188	<.0001	50
Treated diabetes	0.471 ± 0.151	.002	51
Procedural			
No. of ITAs used to graft severely stenosed (≥70%) coronary arteries	−0.294 ± 0.113	.009	91
Moderate CAD bypassed	−0.128 ± 0.135	.3	Forced in
Late phase			
Demography			
Older age§	1.27 ± 0.044	<.0001	100
Weight	0.224 ± 0.057	<.0001	67
Status/symptoms			
Prior myocardial infarction	0.166 ± 0.032	<.0001	100
NYHA class III/IV	0.073 ± 0.032	.02	76
Comorbidities			
Peripheral vascular disease	0.316 ± 0.056	<.0001	100
Prior stroke	0.279 ± 0.089	.002	93
Heart failure	0.248 ± 0.090	.006	98
Treated diabetes	0.447 ± 0.049	<.0001	100
Elevated triglycerides	0.089 ± 0.040	.02	80
History of smoking	0.299 ± 0.034	<.0001	100
Coronary anatomy			
No. of systems diseased¶	0.114 ± 0.031	.0003	95
Procedural			
No. of ITAs used to graft severely stenosed (≥70%) coronary arteries	−0.224 ± 0.030	<.0001	91
Moderate CAD bypassed	−0.114 ± 0.038	.003	Forced in

SE, Standard error; BMI, body mass index; NYHA, New York Heart Association; ITA, internal thoracic artery; CAD, coronary artery disease. *Percent of times factor appeared in 500 bootstrap models. †Exp(age/50), exponential transformation. ‡(25/BMI)², inverse squared transformation. §(Age/50)², squared transformation. ||(kg/80)², squared transformation. ¶1, 2, or 3 systems, ≥50% stenosis.

TABLE E3. Risk factors for mortality after CABG with 1 system of moderate CAD (n = 8531): reference group = ITA grafting versus SV grafting versus nongrafted

Factor	Estimate ± SE	P	Reliability, %*
Early phase			
Demography			
Older age†	0.399 ± 0.087	<.0001	68
Lower BMI‡	0.320 ± 0.102	.002	55
Status/symptoms			
NYHA class II	−0.331 ± 0.135	.01	90
Comorbidities			
Peripheral vascular disease	0.682 ± 0.154	<.0001	72
Prior stroke	0.598 ± 0.214	.005	54
Heart failure	0.824 ± 0.187	<.0001	50
Treated diabetes	0.514 ± 0.151	.0006	51
Procedural			
No. of ITAs used to graft severely stenosed (≥70%) coronary arteries	−0.48 ± 0.118	<.0001	91
ITA graft to moderate CAD	−0.76 ± 0.20	.0001	Forced in
SV graft to moderate CAD	0.0088 ± 0.034	.8	Forced in
Late phase			
Demography			
Older age§	1.26 ± 0.043	<.0001	100
Weight	0.234 ± 0.058	<.0001	67
Status/symptoms			
Prior myocardial infarction	0.163 ± 0.032	<.0001	100
NYHA class III/IV	0.069 ± 0.033	.03	76
Comorbidities			
Peripheral vascular disease	0.308 ± 0.057	<.0001	100
Prior stroke	0.285 ± 0.092	.002	93
Heart failure	0.233 ± 0.093	.01	98
Treated diabetes	0.448 ± 0.049	<.0001	100
Elevated triglycerides	0.088 ± 0.041	.03	80
History of smoking	0.307 ± 0.034	<.0001	100
Coronary anatomy			
No. of systems diseased¶	0.117 ± 0.032	.0002	95
Procedural			
No. of ITAs used to graft severely stenosed (≥70%) coronary arteries	−0.265 ± 0.032	<.0001	91
ITA graft to moderate CAD	−0.242 ± 0.051	<.0001	Forced in
SV graft to moderate CAD	−0.047 ± 0.039	.2	Forced in

SE, Standard error; BMI, body mass index; NYHA, New York Heart Association; ITA, internal thoracic artery; CAD, coronary artery disease; SV, saphenous vein. *Percentage of times factor appeared in 500 bootstrap models. †Exp(age/50), exponential transformation. ‡(25/BMI)², inverse squared transformation. §(age/50)², squared transformation. ||(kg/80)², squared transformation. ¶1, 2, or 3 systems, ≥50% stenosis.