To graft or not to graft? Do coronary artery characteristics influence early outcomes of coronary artery bypass surgery? Analysis of coronary anastomoses of 5171 patients

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Objective: Small coronary size and extensive atherosclerosis pose operative challenges during coronary artery bypass grafting. We investigated the influence of coronary characteristics on early operative outcome.

Methods: Prospectively collected data for 5171 patients undergoing first-time coronary artery bypass grafting from April 1, 1999, to December 31, 2007, were analyzed. Coronary diameter estimated or probe-gauged intraoperatively was regarded as small if 1.25 mm or less. Coronary atherosclerosis was graded as none/mild or moderate/severe. Their influence on postoperative major adverse cardiac events, myocardial infarction or reoperation for graft failure, post-cardiotomy shock, and operative mortality, was investigated.

Results: Of 14,019 coronary anastomoses, 4417 coronaries (31.5%) were small and 5895 coronaries (43.4%) had moderate/severe atherosclerosis. All grafted coronaries were small in 1091 patients (21.1%). Left anterior descending, circumflex, and right coronary arteries received grafts in 94.8% of patients (n = 4903), 74.3% of patients (n = 3842), and 72.5% of patients (n = 3751), with corresponding rates of 31.7%, 31.7%, and 32.6% for small-caliber arteries, 44.4%, 33.3%, and 47.2% for moderate/severe atherosclerosis, and 0.6%, 0.5%, and 3.4% for endarterectomy. Postoperative major adverse cardiac events occurred in 236 patients (4.6%). There was no clear evidence that small caliber of half or more distal anastomoses in a patient (odds ratio, 1.36; 95% confidence interval, 0.97–1.94; $P = .07$) increased the risk of a major adverse cardiac event, but incomplete revascularization (odds ratio, 1.87; 95% confidence interval, 1.03–3.39; $P = .04$) and moderate/severe atherosclerosis of the left anterior descending artery (odds ratio 1.37; 95% confidence interval, 1.01–1.87; $P = .04$) did increase the risk.

Conclusion: Grafting small coronaries did not significantly increase the risk of an early postoperative major adverse cardiac event, but incomplete revascularization did increase the risk. Our findings support grafting small coronaries when technically feasible to prevent incomplete revascularization. (J Thorac Cardiovasc Surg 2010;140:66-72)

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The aggressive pursuit of nonsurgical revascularization selects patients with challenging coronary artery disease for surgical revascularization.^{1,2} Because surgery is preferred to angioplasty and stenting for diabetic patients,^{3,4}

the increasing number of this cohort of patients undergoing coronary artery bypass grafting (CABG) also contributes to this problem. Not infrequently therefore, intraoperative decisions regarding the suitability for, and prognostic benefit of, grafting these difficult coronaries become a dilemma.

The impact of grafting small coronary arteries on the outcome of CABG is not clear. Attempts to explain the comparatively poor operative outcomes in female patients by smaller-caliber coronary circulation have been unsuccessful.⁵ A similar notion as the cause for the difference in operative outcome between Caucasian and UK South Asian men has not been substantiated.⁶ To address this problem, early studies⁷⁻⁹ used a cutoff of 1.5 mm in diameter to define small coronaries, but in current practice this coronary size would not be considered small. An additional setback of these historical series is their assessment of the impact of the size of a single coronary artery, the left anterior descending artery in most cases,^{10,11} in the era when the left internal thoracic artery was not routinely used for bypass grafting. Furthermore, the influence of other coronary characteristics frequently coexistent with small luminal diameter (eg, severe atherosclerosis) was not investigated.

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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CI	= confidence interval
ECG	= electrocardiogram
MACE	= major adverse cardiac event
OR	= odds ratio

In the current era, with improved surgical techniques, regular use of the left internal thoracic artery, and better perioperative care, the implications of constructing anastomoses on small target coronary arteries or severely atherosclerotic vessels are not clearly defined. If these vessels are left ungrafted, however, the resulting incomplete myocardial revascularization imposes prognostic liabilities for both early and late outcomes.¹²

This retrospective study investigated the coronary artery diameter and severity of atherosclerosis in the 3 major territories of the coronary circulation in patients who underwent primary isolated CABG. The study objectives were to (1) assess the prevalence and distribution of coronary arteries with small luminal diameter (≤ 1.25 mm) and moderate/severe coronary atherosclerosis; (2) examine the relationship between these coronary characteristics and early major adverse cardiac events (MACEs); the combined end points of postoperative myocardial infarction/reintervention for early graft failure, postcardiotomy shock, and operative mortality; and (3) determine the incidence of incomplete myocardial revascularization and its impact on early postoperative MACE.

MATERIALS AND METHODS

Patients

Clinical data are prospectively collected for all patients undergoing cardiac surgery at the university teaching hospital of Castle Hill Hospital and stored in an electronic database. The database is run by dedicated data managers who regularly update and validate entries. After approval was obtained from the local medical and ethics committee and a waiver for individual patient consent, the database was interrogated, and demographic, preoperative, intraoperative, and postoperative data were retrieved for each patient who underwent isolated primary CABG at Castle Hill Hospital between April 1, 1999, and December 31, 2007.

During this period, CABG was performed predominantly with cardiopulmonary bypass and blood cardioplegic or crossclamp fibrillatory arrest; off-pump CABG constituted 7.3% of procedures ($n = 379$). Our main revascularization strategy involved grafting the left internal thoracic artery to the left anterior descending artery and saphenous vein conduits, harvested by the open technique, to other coronary artery targets. Other arterial conduits, such as the radial ($n = 585$) and right internal thoracic arteries ($n = 148$), were used less frequently. All anastomoses were hand-sewn, and intraoperative patency was crudely assessed by resistance to the infusion of blood or blood cardioplegia through the graft after constructing the distal anastomoses. After surgery, 300 mg of aspirin was administered per rectum within 6 hours and continued orally at 75 mg daily from the first postoperative day. Blood pressure, heart rate, central venous pressure electrocardiographic tracings, oxygen saturation, and urinary output were continuously monitored for 48 hours postoperatively. Routine 12-lead

electrocardiograms (ECGs) were performed on the first, second, and fourth or fifth postoperative days. Whenever a cardiac event was suspected, a 12-lead ECG, an assay of cardiac biomarker levels (although less consistently) (creatinine kinase-MB in the early study period and troponin T in the later period), and transesophageal echocardiography were performed. Reintervention for ischemic ECG changes with hemodynamic deterioration involved reopening and regrafting for occluded grafts, unkinking grafts, and releasing extrinsic graft compression. Angioplasty was performed in 2 stable patients who had recurrent myocardial ischemia with persistent ECG changes after 5 postoperative days.

Definitions

Coronary artery characteristics were defined on the basis of intraoperative findings. Target coronary arteries were visually assessed, palpated, and calibrated with a probe after arteriotomy. The coronary diameter was recorded as 1.0 mm, 1.25 mm, 1.5 mm, 1.75 mm, 2.0 mm, or greater than 2.0 mm. Severity of coronary atherosclerosis was graded as none, mild (discrete isolated plaques on anterior or posterior wall, not at site of arteriotomy or beyond), moderate (plaques on both anterior and posterior walls, with arteriotomy sometimes encroaching on plaques), or severe (diffuse atherosclerosis extends beyond arteriotomy site).

Coronary arteries were classified as small if their diameter was 1.25 mm or less, and the extent of coronary atherosclerosis was dichotomized into none/mild and moderate/severe. Of 5500 patients in the database, 324 were excluded from the study because they did not have complete entries for the coronary artery diameter, extent of atherosclerosis (principal independent variables, $n = 228$), or postoperative MACE (dependent variable, $n = 96$). Myocardial revascularization was considered incomplete if any of 3 ischemic territories with coronary stenoses greater than 70% did not receive a bypass graft.

Statistical Analysis

The study primary end point was MACE, a composite of 1) postoperative myocardial infarction (new and persistent S-T changes or new Q waves on electrocardiography) or reintervention for early graft failure in the form of regrafting a coronary artery or angioplasty/stenting; 2) postcardiotomy shock requiring mechanical support with intraaortic balloon pump or ventricular assist device in addition to inotropes; and 3) operative mortality (death during hospitalization or within 30 days of surgery).

Categorical variables are reported as percentages, continuous variables with symmetric distribution are reported as mean $\pm$ standard deviation, and continuous variables with asymmetric distribution as median with the 25th and 75th percentiles are reported as interquartile range. Univariate associations with postoperative MACE were determined for each preoperative and intraoperative variable (Appendix 1) using logistic regression analysis. Preoperative and intraoperative variables that exhibited some evidence of univariate association ($P < .1$) were then included in a backward, stepwise, multifactorial logistic regression model (Appendix 2) to identify predictors for postoperative MACE. Statistical analysis was performed using the Statistical Package for the Social Sciences version 15.0 for Windows (SPSS Inc, Chicago, IL).

RESULTS

Table 1 shows the clinical profile of the 5171 study patients. Mean age was 65 ± 9 years, and 21.5% ($n = 1112$) were female. The majority of patients ($n = 3656$, 70.7%) had 3-vessel disease, and 13.7% ($n = 708$) previously underwent angioplasty and stenting. Diabetes mellitus and peripheral vascular disease were present in 19.7% of patients ($n = 1019$) and 10.9% of patients ($n = 564$), respectively. Operations were predominantly elective ($n = 4026$,

TABLE 1. Clinical profiles of patients undergoing coronary artery bypass grafting

Variable	All patients n (%)	Patients without MACE* n (%)	Patients with MACE* n (%)	P value
No. of patients	5171	4935	236	
Demographics				
Female gender	1112 (21.5)	1056 (21.4)	56 (5.0)	.48
Mean age (y) $\pm$ SD	65 $\pm$ 9	65 $\pm$ 9	68 $\pm$ 9	<.001
Cardiac morbidity				
Prior myocardial infarction	2027 (39.2)	1896 (38.4)	131 (55.5)	<.001
Congestive heart failure	726 (14.0)	657 (13.3)	69 (29.2)	<.001
Left ventricular ejection fraction				<.001
0.50	3889 (75.2)	3775 (76.5)	114 (48.3)	
0.30–0.50	998 (19.3)	936 (19.0)	62 (26.3)	
0.30	284 (5.5)	224 (4.5)	60 (25.4)	
Angiographic findings				
Extent of coronary artery disease				<.001
Single vessel	259 (5.0)	255 (5.2)	4 (1.7)	
Double vessel	1256 (24.3)	1219 (24.7)	37 (15.7)	
Triple vessel	3656 (70.7)	3461 (70.1)	195 (82.6)	
Left main stem disease	1513 (29.3)	1417 (28.7)	96 (40.7)	<.001
Graft details				
Bypass graft territories				
LAD	4903 (94.8)	4678 (94.8)	225 (95.3)	.71
RCA distribution	3751 (72.5)	3566 (72.3)	185 (78.4)	.04
Circumflex system	3842 (74.3)	3671 (74.4)	171 (72.5)	.50
Arterial conduits	4603 (89.0)	4413 (89.4)	190 (80.5)	<.001
LITA	4559 (88.2)	4370 (88.6)	189 (80.1)	<.001

CABG, Coronary artery bypass grafting; LAD, left anterior descending artery; LITA, left internal thoracic artery; MACE, major adverse cardiac event; RCA, right coronary artery; SD, standard deviation. *MACE, a composite of postoperative myocardial infarction, regrafting for early postoperative graft failure, postcardiotomy shock requiring intraaortic balloon pump, or ventricular assist device in addition to inotropes and death in-hospital or within 30 days of operation.

77.9%), and most patients ($n = 3272$, 63.3%) received 3 or more bypass grafts. At least 1 grafted coronary was small in 2369 patients (45.8%), and 2774 patients (53.6%) had moderate/severe atherosclerosis of a dominant right coronary or left anterior descending artery.

Characteristics of Grafted Coronary Arteries

A total of 14,019 anastomoses were performed. The distribution of the coronary anastomoses is displayed in Table 2. The left anterior descending artery was grafted in 94.8% of patients ($n = 4903$), the circumflex system was grafted in 74.3% of patients ($n = 3842$), the right coronary artery or a tributary was grafted in 72.5% of patients ($n = 3791$), the diagonal branches were grafted in 18.7% of patients ($n = 968$), and the intermediate coronary artery was grafted in 4.0% of patients ($n = 205$). Two branches each, of the circumflex and diagonal arteries, received bypass grafts in 5.6% ($n = 292$) and 0.2% ($n = 9$) of patients, respectively.

In general, 4460 of the 14,019 grafted coronaries (31.8%) were 1.25 mm or less in diameter, and 5895 (42.1%) had moderate/severe atherosclerosis. All grafted coronaries were small in 1091 patients (21.1%), and half or more grafted coronaries were small in 1729 patients (33.4%).

Of 4903 left anterior descending arteries, 1553 (31.7%) were of small caliber and 2175 (44.4%) had moderate/severe atherosclerosis. Endarterectomy was performed in

28 patients (0.6%). For the right coronary artery, 1235 of 3791 (32.6%) were of small caliber and 1789 (47.2%) had moderate/severe atherosclerosis. A right coronary artery endarterectomy was performed in 128 patients (3.4%).

The circumflex system (obtuse marginal arteries) was of small diameter in 1311 of 4134 patients (31.7%), and 1377 patients (33.3%) had moderate/severe atherosclerosis.

There were notable gender differences in the characteristics of grafted coronary arteries. The female patients more frequently had small coronaries than the male patients ($P < .0001$); more than half the grafted coronaries in 40.7% of women versus 31.5% of men, and all grafted coronaries in 28.0% of women versus 19.2% of men, were of small diameter. A greater proportion of women had a small left anterior descending artery compared with men (39.4% vs 27.5%, $P < .0001$), but a similar percentage of female to male patients (25.1% and 23.5%, $P = .28$) had small right coronary arteries. Conversely, more men had moderate/severe atherosclerosis of the left anterior descending artery (43.1% vs 38.3% for women, $P = .004$) and the right coronary artery (36.1% vs 29.2% for women, $P < .0001$).

Myocardial revascularization was incomplete in 5.0% of patients ($n = 261$). The incidence of incomplete revascularization was higher in women (7.6% vs 4.4%, $P < .0001$).

TABLE 2. Coronary characteristics of 5171 patients undergoing coronary artery bypass grafting

Coronary characteristic	Total no. of measurements	Frequency n (%)
Coronary size (mm)	14,019	
1.0		316 (2.3)
1.25		4144 (29.6)
1.50		5562 (39.7)
1.75		2650 (18.9)
≥2.0		1337 (9.5)
Coronary atherosclerosis	14,019	
None		4454 (31.8)
Mild		3670 (26.2)
Moderate		3462 (24.7)
Severe		2433 (17.4)
Endarterectomy		170 (1.2)
Bypass conduits	14,019	
Saphenous vein		8663 (61.8)
Left internal thoracic artery		4621 (33.0)
Right internal thoracic artery		148 (1.1)
Radial artery		585 (4.2)
Other		2 (0)
Coronary diameter ≤1.25 mm		
Left anterior descending artery	4903	1553 (31.7)
Right coronary artery	3791	1235 (32.6)
Circumflex	4134	1311 (31.7)
Diagonal/intermediate	1191	235 (19.7)
Moderate/severe atherosclerosis		
Left anterior descending artery	4903	2175 (44.4)
Right coronary artery	3791	1789 (47.2)
Circumflex	4134	1377 (33.3)
Diagonal/intermediate	1191	304 (25.5)
Endarterectomy		
Left anterior descending artery	4903	28 (0.6)
Right coronary artery	3791	128 (3.4)
Circumflex	4134	12 (0.3)
Diagonal/intermediate	1191	4 (0.3)

Diabetes did not exhibit a univariate association with coronary artery diameter or incomplete myocardial revascularization. However, compared with nondiabetic patients, diabetic patients were more likely to have moderate/severe atherosclerosis of the right coronary artery (37.7% vs 34.0%, $P = .03$) and left anterior descending artery (46.4% vs 41.2%, $P = .003$).

Relationship Between Coronary Characteristics and Operative Outcome

Postoperatively, MACE occurred in 236 patients (4.6%); myocardial infarction without reintervention in 54 patients

(10%), reintervention for early graft failure in 20 patients (0.4%), significant postoperative hemodynamic instability requiring intraaortic balloon pump or ventricular assist device support additional to inotropic infusions in 72 patients (1.4%), and operative mortality in 90 patients (1.7%). Creatine kinase-MB or troponin T, available for 25 of 68 patients with postoperative myocardial infarction, was elevated.

Univariate analysis revealed strong associations between coronary artery characteristics and MACE (Appendix 2). Whereas small caliber and moderate/severe atherosclerosis of the right coronary artery and moderate/severe atherosclerosis of the left anterior descending artery were associated with an increase in the incidence of MACE, a left internal thoracic artery graft decreased the risk. However, these associations were not maintained by multivariate analysis. The risk factors for MACE by multivariate analysis are shown in Table 3. Moderate/severe atherosclerosis of the left anterior descending artery (odds ratio [OR], 1.37; 95% confidence interval [CI], 1.01–1.87; $P = .04$), severe atherosclerosis of the right coronary requiring endarterectomy (OR, 2.45; 95% CI, 1.21–4.98; $P = .01$), and incomplete revascularization (OR, 1.87; 95% CI, 1.03–3.39; $P = .04$) retained a statistically significant association with MACE. Small coronary caliber affecting half or more of the grafted coronaries in a patient did not exhibit a significant independent influence on MACE (OR, 1.36; 95% CI, 0.97–1.94; $P = .07$). Other postoperative complications are listed in Table 4.

DISCUSSION

Poor coronary characteristics are not uncommon in current practice. They increase the operative difficulty and complexity of CABG, and have been shown to be a frequent cause of modification of the “*ab initio* revascularization strategy.”^{13,14} The present study reveals that small coronary artery targets and severe coronary atherosclerosis are common in patients undergoing CABG, with up to 46% of patients with at least 1 coronary artery of small diameter (≤1.25 mm), 21% of patients with small coronaries in all grafted territories, and 54% of patients with moderate/severe atherosclerosis in 1 of the major target vessels. Although women were more likely to have small-diameter vessels, men more often had moderate/severe coronary atherosclerosis.

Coronary artery characteristics at the site of anastomoses directly affect the outcome of CABG. Our study shows that extensive atherosclerosis of the left anterior descending artery and diffuse severe atherosclerosis of the right coronary artery requiring endarterectomy were independent predictors of MACE after CABG. Apart from the technical challenges of constructing anastomoses in these settings, the associated morphologic and physiologic changes, such as a decrease in compliance, resistance and reactivity of

TABLE 3. Risk factors by multivariate analysis for major adverse cardiac events after coronary artery bypass grafting

Covariate	OR	95% CI	P value
Ejection fraction < 0.30	7.31	4.92–10.86	<.001
Emergency surgery	3.66	1.56–8.58	.003
Renal insufficiency	2.69	1.35–5.36	.005
Right coronary endarterectomy	2.45	1.21–4.98	.01
Incomplete revascularization	1.87	1.03–3.39	.04
Intravenous nitrates/heparin until surgery	1.73	1.05–2.84	.03
Peripheral vascular disease	1.68	1.12–2.52	.01
Previous stroke	1.64	1.06–2.55	.03
Moderate/severe atherosclerosis of left anterior descending artery	1.37	1.01–1.87	.04
Age	1.04	1.02–1.06	<.001
Cardiopulmonary bypass time	1.01	1.01–1.02	<.001
≥50% grafted coronaries ≤1.25 mm in diameter	1.36	0.97–1.94	.07

CI, Confidence interval; OR, odds ratio.

the coronary vascular bed, and rigidity of the coronary artery, can compromise the adequacy of distal coronary flow. Nonsurgical series¹⁵ have shown that nonobstructive coronary disease and coronary calcification are associated with increased mortality. Similarly, an increase in the incidence of MACE has been observed after endarterectomy of the right coronary artery.¹⁶

Notable, and somewhat surprising, is our finding that constructing coronary anastomoses with small-diameter vessels (≤1.25 mm) per se did not significantly increase the risk of MACE in the early postoperative period after CABG. In view of the procedural difficulty of small-vessel anastomoses, this represents an improvement when compared with historical data, probably because of better technical skills resulting from a growing experience in dealing with these challenging cases that are more prevalent in current practice, as well as changes in surgical and perioperative care. For example, the historical data of the Northern New England Cardiovascular Disease Study Group^{10,11} demonstrated a strong association between the size of the left anterior descending artery and operative mortality. However, in those series, less than 80% of patients received an internal thoracic artery graft. Also, neither the influence of the size of other major coronary arteries nor the extent of atherosclerosis or incomplete revascularization was explored in these earlier studies. A possible explanation of our finding is provided by the data of Cigarroa and colleagues,¹⁷ which showed an increase in the size of the coronaries after bypass grafting. Small vessels in particular exhibited a significant increase in diameter postoperatively if they received arterial grafts. Another reason for our finding is the proclivity to underestimate or undergauge the size of chronically underfilled and collapsed coronaries that have the potential to open and dilate with improved antegrade blood flow after grafting.¹⁸ The reliability of angiography

in determining the suitability of coronary size and degree of atherosclerosis for bypass grafting has also been questioned^{19,20} and was not considered in this study. Although our findings may seem counterintuitive, it is corroborated by the report of Mickleborough and associates.⁵ In their study, small vessel was not a predictor of postoperative myocardial infarction or operative mortality, but diffuse disease with or without endarterectomy had a univariate association with operative mortality. Notably, vessel quality did not influence long-term survival. Providing, therefore, it is technically feasible to construct an anastomosis on a coronary artery, small coronary diameter on its own should not be seen as a contraindication. The stronger consideration should be whether a viable anastomosis can be performed with the coronary artery rather than an anticipation of a poor outcome resulting from grafting small coronaries, especially in patients with good left ventricular function, as did the majority of patients in this study.

Increasing complexity of surgery for coronary artery disease, as often occurs with difficult coronary targets, is the principal cause of incomplete revascularization.^{21,22} Our study, as well as others,¹² found a powerful correlation between incomplete revascularization and postoperative MACE. The contrasting impacts of small coronaries and incomplete revascularization on early operative outcome have major implications for intraoperative decision-making. The present study supports undertaking the challenging task of constructing anastomoses with small coronaries when technically feasible rather than abandoning these coronaries and causing incomplete myocardial revascularization, which increases the risk of early postoperative MACE. The present study also supports choosing to graft small coronaries over performing endarterectomy of the right coronary artery. Ramstrom and associates⁹ examined the effect of arterial grafts in patients with small-vessel disease (defined as ≤1.5 cm in diameter) in a small group of 200 patients. They reported higher early operative mortality among women, patients with “small-vessel disease,” and patients with incomplete revascularization, but they did not have sufficient number of events to explore independent associations between operative mortality and any of these variables. Again, as in other previous studies, only single coronary territories were considered.

Our study replicates well-known findings regarding poor surgical outcome in female patients compared with male patients,²³ and diabetic patients compared with nondiabetic patients,²⁴ and showed that neither gender nor diabetes alone increased the risk of MACE. Although a prejudicial influence of coronary artery size was not established, this study highlights the influential roles of other factors, such as moderate and severe atherosclerosis of the left anterior descending artery, severe right coronary artery atherosclerosis requiring endarterectomy, and incomplete myocardial revascularization, on early outcomes.

TABLE 4. Postoperative complications after coronary artery bypass grafting

Postoperative complications	Frequency, n (%) N = 5171
Inotropes	1073 (20.8)
Reopening for bleeding/tamponade	143 (2.8)
Atrial fibrillation	1437 (27.8)
Neurologic dysfunction	120 (2.3)
Renal insufficiency	264 (5.1)
Readmission to intensive care	129 (2.5)
Pulmonary complications	847 (16.4)
Median postoperative hospital days	6 (interquartile range, 6–8)

Study Limitations

In practice, the assessment of coronary size to inform the decision to graft or not to graft a vessel is subjective and can be further complicated by the unreliability of preoperative angiograms and underfilling of the vessels. The use of graduated probes, however, reduced the interobserver variability in this study. Another limitation is the lack of direct evaluation of graft patency. Because our patients did not routinely undergo intraoperative graft imaging or postoperative coronary angiography, these data were not available for scrutiny. Although this would have added a different perspective to this study, angiographic findings do not always correlate with clinical outcomes, which were the measures of interest in this study. Also, the diagnosis of postoperative myocardial infarction mainly on the basis of ECG changes may be criticized. The validity of cardiac biomarkers such as troponin T, assayed in some of our patients, depends on the interval between the time of myocardial infarction and the blood test, and the appropriate level of the serum biomarker that indicates a cardiac event occurred. Both of these were uncertain in the majority of patients, and the level of troponin T consistent with postoperative myocardial infarction is still debatable. Although the American College of Cardiology/American Heart Association guidelines²⁵ recommend the use of ECG and cardiac biomarkers for the diagnosis of postoperative myocardial infarction after non-cardiac surgery, they recognize the high sensitivity of 12-lead ECGs and the limitations of biomarkers, which are even greater after cardiac surgery. However, there was complete concordance between cardiac enzyme increase and ECG changes in support of postoperative myocardial infarction in patients with both parameters. Finally, we did not have the necessary data to relate individual coronary artery anastomoses with outcomes for specific coronary territories; thus, we are not able to comment on the regional impact of the characteristics of individual coronaries.

CONCLUSIONS

Poor-quality coronary arteries are commonly encountered in patients undergoing CABG in current practice.

In our experience, up to 32% of target coronaries are small and 42% have moderate/severe atherosclerosis. If coronaries with a luminal diameter of 1.25 cm or more were considered ungraftable, 21% of our patients would be inoperable and 46% would have incomplete revascularization on the basis of size alone. Fortunately, this difficulty is not insurmountable in the current era. In our experience, grafting small coronaries when technically feasible did not increase the risk of early MACE. However, incomplete revascularization that can result from avoidance of small coronaries had a direct link with MACE in the early postoperative period. Our data also suggest that a strategy of grafting small coronaries is less likely to cause MACE compared with endarterectomy, especially of the right coronary artery. A prospective study is warranted to further clarify the impact of coronary characteristics on the late outcome of CABG.

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APPENDIX 1. PREOPERATIVE AND INTRAOPERATIVE VARIABLES TESTED FOR UNIVARIATE ASSOCIATIONS WITH MAJOR ADVERSE CARDIAC EVENTS

Categorical variables

Angina severity using the Canadian Cardiovascular Society classification system (I, II, III, IV)
 Prior myocardial infarction
 Cardiac failure
 Hypertension
 Preoperative permanent pacemaker or defibrillator
 Prior percutaneous intervention
 Preoperative intravenous heparin and nitrates
 Presence of left main stem disease
 Left ventricular systolic function (<0.30, 0.30–0.50, >0.50)
 Diabetes
 Renal insufficiency or dialysis (creatinine > 200 μ mol/L)
 Peripheral vascular disease
 Previous stroke
 Chronic obstructive airways disease
 Sites of coronary anastomoses (left anterior descending, right coronary territory, circumflex system)
 Size of coronary arteries at site of anastomoses (small [≤ 1.25 mm], adequate [> 1.25 mm])
 Extent of atherosclerosis of target coronaries (none/mild, moderate/severe)
 Endarterectomy
 Bypass conduits (left internal thoracic artery, others)
 Incomplete revascularization
 Priority of operation (elective, urgent, emergency)

Continuous variables

Age
 Body mass index
 No. of diseased coronary arteries
 Cardiopulmonary bypass duration
 Crossclamp time

APPENDIX 2. Univariate factors associated with major adverse cardiac events after coronary artery bypass grafting

Variables	OR	95% CI	P value
Ejection fraction			
0.30	9.78	6.98–13.71	<.001
0.30–0.50	2.17	1.57–3.0	<.001
Surgery priority			
Emergency	6.25	3.42–11.42	<.001
Urgent	2.56	1.93–3.38	<.001
Renal insufficiency	4.44	2.51–7.86	<.001
Congestive heart failure			
Current	4.21	2.98–5.96	<.001
Past	1.81	1.12–2.90	.02
Intravenous nitrates/heparin	3.74	2.72–5.12	<.001
Right coronary endarterectomy	2.48	1.37–4.46	.002
Peripheral vascular disease	2.45	1.77–3.39	<.001
Previous stroke	2.07	1.42–3.01	<.001
Number of coronary artery diseased	2.07	1.51–283	<.001
Incomplete revascularization	1.82	1.13–2.93	.01
Prior myocardial infarction	1.77	1.36–2.30	<.001
Chronic obstructive pulmonary disease	1.71	1.19–2.46	.004
Left main stem disease	1.71	1.31–2.24	<.001
Moderate/severe atherosclerosis of left anterior descending artery	1.69	1.30–2.20	<.001
Moderate/severe atherosclerosis of right coronary artery	1.56	1.19–2.03	.001
Diabetes mellitus	1.43	1.05–1.94	.02
Right coronary artery graft	1.38	1.0–1.89	.05
Right coronary artery diameter	1.36	1.02–1.82	.04
≤ 1.25 mm			
$\geq 50\%$ grafted coronaries ≤ 1.25 mm	1.28	0.98–1.68	.07
Left anterior descending artery	1.28	0.97–1.69	.08
≤ 1.25 mm			
Age	1.04	1.03–1.06	<.001
Cardiopulmonary bypass duration	1.01	1.01–1.02	<.001
Aortic crossclamp time	1.01	1.0–1.02	.008
Left internal thoracic artery use	0.55	0.38–0.76	<.001

CI, Confidence interval; OR, odds ratio.