How many arterial grafts are enough? A population-based study of midterm outcomes

Veena Guru, MD,^{a,b} Stephen E. Fremes, MD, MSc,^a and Jack V. Tu, MD, PhD^b

V. Guru, S. Fremes, and J. Tu

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From the Divisions of Cardiovascular Surgery^a and General Internal Medicine, Sunnybrook and Women's College Health Sciences Centre, and the Institute for Clinical Evaluative Sciences,^b University of Toronto, Toronto, Ontario, Canada.

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Address for reprints: Veena Guru, MD, Institute For Clinical Evaluative Sciences, 2075 Bayview Ave, G106, Toronto, Ontario M4N 3M5, Canada (E-mail: veena.guru@utoronto.ca).

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Objective: Current evidence suggests arterial grafting improves freedom from cardiac events after coronary artery bypass graft surgery. It has been shown that 2 arterial grafts provide improved outcome compared with 1 arterial graft. This population study seeks to understand trends in arterial graft use and midterm outcomes of patients receiving 1, 2, or 3 arterial grafts.

Methods: This study is a retrospective population-based cohort of 53,727 patients (47,214 with 1 arterial graft, 5466 with 2 arterial grafts, and 1047 with 3 arterial grafts) undergoing isolated coronary artery bypass graft surgery in Ontario (1991-2001). The patients were followed by using linked clinical and administrative data, with complete follow-up until December 31, 2003 (average patient years of follow-up: 6 years for those with 1 arterial graft, 5 years for those with 2 arterial grafts, and 4 years for those with 3 arterial grafts). Propensity matching was used to compare outcomes between patients receiving 1 versus 2 arterial grafts, 2 versus 3 arterial grafts, and 1 versus 2 or 3 arterial grafts. The outcomes included death, repeat revascularization (angioplasty or coronary artery bypass grafting), cardiac readmission (readmission for angina, heart failure, and myocardial infarction), and a composite comprising all of these outcomes. Cox proportional hazards models were used to compare outcomes for propensity-matched patients. Subgroup analyses of various patient risk categories defined by the tercile of predicted 30-day mortality risk were conducted between propensity-matched individuals.

Results: The use of multiple arterial grafts (defined as >1 arterial graft) increased mainly in the latter part of the study, from 4% in 1991 to 27% in 2001. Four thousand nine hundred sixty-eight patients were propensity matched (91% of patients receiving 2 arterial grafts) to compare outcomes with those of patients receiving 1 arterial graft. One thousand twenty-eight patients were propensity matched (98% of those receiving 3 arterial grafts) to compare outcomes with those of patients receiving 2 arterial grafts. Five thousand four hundred ninety-one patients were propensity matched (84% of those receiving 2 or 3 arterial grafts) to compare outcomes with those of patients receiving 1 arterial graft. Two arterial grafts were shown to be protective for cardiac readmission (0.8; 95% confidence interval, 0.76-0.92) and a composite outcome (0.9; 95% confidence interval, 0.72-0.95) compared with 1 arterial graft. Two or 3 arterial grafts were further found to improve survival (0.8; 95% confidence interval, 0.72-0.99). In all patient operative risk categories, 2 or 3 arterial grafts were protective for cardiac readmission (hazard ratio, 0.7-0.8) and the composite outcome (hazard ratio, 0.8). There was no difference in the Cox hazard ratios of propensity-matched patients in the comparison of the groups receiving 3 versus 2 arterial grafts.

Conclusions: Few patients received more than 1 arterial graft in our region. There was a survival benefit in receiving 2 or 3 arterial grafts. Patients with low, moderate, and high operative risk receiving 2 or 3 arterial grafts had lower rates of cardiac readmission compared with patients receiving only 1 arterial graft. This suggests that the standard of care should include the use of at least 2 arterial bypasses in all categories of operative risk to allow for optimal midterm outcomes.

The benefits of using the left internal thoracic artery (ITA) over other conduits include its superior long-term patency, freedom from recurrent cardiac events (including revascularization), and improved long-term survival.¹⁻³ It has been recognized that the superiority of the ITA in the long term has been due to the fact that saphenous vein grafts are more likely to experience early closure because of early thrombosis, midterm intimal hyperplasia, and late consequent atherosclerosis.¹

The use of bilateral ITAs has also appeared promising, with some reports indicating further outcome benefits than those conferred simply by the use of a left ITA.⁴ However, this evidence has been less homogeneous, with reports of equivocal results.⁵⁻⁸ There are also widely recognized disadvantages associated with the use of a second ITA, including the fact it is time consuming to harvest; is technically more challenging, particularly for grafting more distal targets in the right and circumflex distributions; and might result in an increased incidence of sternal wound complications.⁹ Furthermore, there is little evidence regarding the use of 3 arterial grafts. Studies have demonstrated the safety of using 3 arterial bypasses; however, no evidence has indicated improved outcomes.¹⁰

This study explores the use and midterm results associated with 2 or 3 arterial grafts at a population level where varying institutional use, technical performance, and patient risk provide a better estimate of the effectiveness of arterial grafting. Please note that our study relied on established databases that did not contain data on arterial graft type or bypass target location.

Methods

Databases

The Cardiac Care Network database, which included clinical pre-operative data (ie, variables used to appropriately queue patients for surgical intervention and thus no intraoperative data), identified all patients who underwent isolated coronary artery bypass surgery in Ontario between September 1991 and March 31, 2002. These data were linked to 4 administrative databases through the use of unique encrypted identifiers. The Canadian Institutes for Health Information database identified those patients discharged alive from the hospital. The Canadian Institutes for Health Information database also included data on cardiovascular readmissions for acute myocardial infarction, congestive heart failure, and unstable

Abbreviations and Acronyms

CABG = coronary artery bypass graft
CCS = Canadian Cardiovascular Society
ITA = internal thoracic artery
HR = hazard ratio
LAD = left anterior descending

angina. The Registered Persons Database identified out-of-hospital deaths. Socioeconomic status was obtained through linkage of patient postal codes (enumeration area) to Canadian Census data, where each patient's income quintile was estimated on the basis of their primary residence. The Ontario Health Insurance Plan database was used to determine the type of grafts used (in this governmental billing database "arterial graft" was coded as inclusive of all types of arterial conduits, including ITA grafts and radial artery grafts) and repeat revascularization procedures (angioplasty

Figure 1. Trends in arterial graft use in Ontario between fiscal years 1991 and 2001.

TABLE 1. Characteristics and outcomes of all patients (n = 53,727)

Characteristic	One arterial graft (n = 47,214)	Two arterial grafts (n = 5466)	Three arterial grafts (n = 1047)
Mean years of follow-up	6	5	4
Female sex	21%	16%	11%
Age			
<60 y	35%	55%	60%
60-69 y	38%	30%	27%
70-79 y	25%	14%	12%
≥80 y	2%	0.7%	1%
Triage status			
Urgent	47%	46%	46%
Emergency	9%	7%	7%
Comorbidity			
Diabetes	26%	25%	21%
Dialysis	0.8%	0.6%	0.2%
PVD	9%	8%	9%
Cerebrovascular disease	7%	6%	6%
COPD	8%	7%	7%
Cardiac status			
Congestive heart failure	10%	9%	9%
Previous CABG	4%	2%	1%
Grade 3 LVEF	17%	14%	10%
Grade 4 LVEF	4%	2%	1%
Left main disease	18%	18%	17%
Double vessel with PLAD	56%	55%	56%
Three-vessel CAD	6%	5%	5%
CCS III	37%	37%	32%
CCS IV	44%	41%	42%
Income quintile			
1	18%	17%	14%
2	20%	18%	17%
3	21%	20%	21%
4	20%	22%	23%
5	21%	23%	25%
Crude outcomes			
One year			
Mortality	3.3%	1.9%	1.5%
Cardiac readmission	11%	7.8%	5.6%
Repeat revascularization	1.3%	1.2%	1.4%
Composite	13%	9%	7%
Five years			
Mortality	10%	4%	4%
Cardiac readmission	28%	20%	24%
Repeat revascularization	1.3%	1.6%	2.1%
Composite	30%	21%	25%

PVD, Peripheral vascular disease; COPD, chronic obstructive pulmonary disease; CABG, coronary artery bypass grafting; LVEF, left ventricular ejection fraction; PLAD, proximal left anterior descending coronary artery disease; CAD, coronary artery disease; CCS, Canadian Cardiovascular Society Angina Class.

or bypass surgery). A survey of all cardiac surgeons was conducted in 2003 to understand their self-reported use of multiple arterial grafting.

The primary outcomes of interest included death, repeat revascularization, cardiac readmission, and a composite of these outcomes. χ^2 Tests were used for categorical variables and crude outcomes. Greedy propensity matching was carried out to compare patients with 1 arterial graft versus those with 2 arterial grafts and those with 2 arterial grafts versus those with 3 arterial grafts.

Outcomes were analyzed between these groups through comparing patients who closely matched on propensity scores. Propensity score models were created by using logistic regression to predict the probability of a patient receiving 2, 3, and 2 or 3 arterial grafts, including the following variables: age, sex, triage status, era of surgical intervention, institution, income quintile, left ventricular function, Canadian Cardiovascular Society (CCS) class, coronary anatomy, total number of grafts completed, congestive heart failure, previous coronary artery bypass graft (CABG), cerebrovascu-

TABLE 2. Cox hazard ratios of propensity-matched patients undergoing CABG in Ontario

Outcome	Two vs 1 arterial graft (95% CI)	Three vs 2 arterial grafts (95% CI)	Two or 3 vs 1 arterial graft
Pairs (n)	4968	1028	5491
Mean follow-up	5 y (2), 6 y (1)	4 y (3), 5 y (2)	4.5 y (2 or 3), 6 y (1)
Death	0.9 (0.75-1.04)	1.0 (0.62-1.72)	0.8 (0.72-0.99)*
Repeat revascularization	0.9 (0.78-1.03)	1.2 (0.82-1.80)	0.9 (0.81-1.06)
Cardiac readmission	0.8 (0.76-0.92)*	0.9 (0.66-1.09)	0.8 (0.74-0.89)*
Unstable angina	0.9 (0.81-0.99)*	1.0 (0.73-1.26)	0.8 (0.75-0.91)*
Myocardial infarction	0.8 (0.70-0.92)*	1.0 (0.61-1.48)	0.8 (0.73-0.97)*
Congestive heart failure	0.8 (0.72-0.95)*	0.7 (0.45-1.10)	0.8 (0.71-0.93)*
Composite (above outcomes)	0.9 (0.78-0.94)*	0.9 (0.71-1.15)	0.9 (0.77-0.92)*

CABG, Coronary artery bypass grafting; CI, confidence interval. *Significantly different between groups ($P < .05$).

lar disease, peripheral vascular disease, chronic obstructive pulmonary disease, dialysis, and diabetes. Patients were matched on the logit of the propensity score by using a caliper width of 0.2 of the standard deviation of the logit of the propensity score. Four thousand nine hundred sixty-eight of 5466 patients with 2 arterial CABGs were matched on propensity score to patients with 2 arterial CABGs (91% efficiency). One thousand twenty-eight of 1047 patients with 3 arterial CABGs were matched on propensity score to patients with 2 arterial CABGs (98% efficiency). Five thousand four hundred ninety-one of 6513 patients with 2 or 3 arterial CABGs were matched on propensity score to patients with 1 arterial CABG (84% efficiency). The McNemar test was used to check that covariates used in the propensity model were in fact not significantly different between arterial graft groups matched by propensity score. Cox models stratified by pair were constructed for each outcome of interest. Kaplan-Meier curves for the propensity analysis of 2 or 3 arterial grafts versus 1 arterial graft were plotted.

The patients were then divided into low-, moderate-, and high-risk categories, as calculated by the tercile of the predicted 30-day mortality risk. The logistic model constructed for predicted 30-day mortality included the covariates described in the above propensity model. Three separate propensity matches of patients with 2 or 3 arterial grafts versus those with 1 arterial graft were conducted in each of the 3 terciles of risk (low, moderate, and high). The statistical analyses were completed with SAS software (version 8.2; SAS Institute Inc, Cary, NC).

Results

Patient Population

During the study time period between fiscal years 1991 and 2001, 53,727 patients underwent CABG surgery in Ontario with the use of at least 1 arterial graft. The study cohort included 47,214 patients with 1 arterial graft, 5466 patients with 2 arterial grafts, and 1047 patients with 3 arterial grafts, as identified through the Ontario Health Insurance Plan database. The mean follow-up was 6 years for patients with 1 arterial CABG, 5 years for patients with 2 arterial CABGs, and 4 years for patients with 3 arterial CABGs. This decreasing follow-up with increasing numbers of arterial grafts was representative of the institutional trends in the use of 2 or 3 arterial grafts in Ontario, which appeared to have increased in the last 3 years (Figure 1). The institutional use of 2 or 3 arterial grafts varied,

with 6 of 8 institutions in Ontario using this strategy in less than 10% of patients.

Cardiac surgeons, when surveyed, reported much higher rates in the use of multiple arterial grafting, including 50% stating that at least 2 arterial grafts were used in at least half of their patients and 47% of surgeons claiming to use 3 or more arterial grafts in more than 10% of their patients. On survey, a majority of surgeons reported their preferred choice for a second arterial bypass type was the ITA (60% of surgeons), with a significant proportion also using the radial artery (40% of surgeons). There was no preferred third arterial bypass type as half of the surgeons each reported using the ITA or radial artery, respectively.

Women, patients aged 60 years or greater, patients with diabetes, patients undergoing redo CABG, and patients with left ventricular grade 3 or 4 or CCS class III or IV angina were less likely to receive more arterial grafts (Table 1). The unadjusted 1- and 5-year outcome rates for death and cardiac readmission were lower with increasing number of arterial grafts (Table 1). The unadjusted 1- and 5-year outcome rates for repeat revascularization were higher with increasing number of arterial grafts (Table 1).

One Versus 2 Arterial Grafts

Four thousand nine hundred sixty-eight patients with 2 arterial grafts were matched by propensity score to patients with 1 arterial graft. The clinical characteristics of the patients were statistically no different after propensity matching. The mean years of follow-up for matched patients with 1 arterial graft was 6 years compared with 5 years for patients with 2 arterial grafts. The use of 2 arterial grafts was protective for cardiac readmission, with a hazard ratio (HR) of 0.8 (Table 2). This outcome was further delineated by primary readmission diagnosis (Table 2). The readmission rates for unstable angina, myocardial infarction, and congestive heart failure were all found to be significantly lower for patients with 2 arterial grafts (Table 2). Two arterial grafts were protective for the composite outcome, with an HR of 0.9 (Table 2).

Two Versus 3 Arterial Grafts

One thousand twenty-eight patients with 3 arterial grafts were matched by propensity score to patients with 2 arterial grafts. The mean years of follow-up for matched patients with 2 arterial grafts was 5 years compared with 4 years for patients with 3 arterial grafts. There was no significant difference in outcomes observed for those with 2 versus 3 arterial grafts (Table 2).

Two or 3 Arterial Grafts Versus 1 Arterial Grafts

Five thousand four hundred ninety-one patients with 2 or 3 arterial grafts were matched by propensity score to patients with 1 arterial graft. The clinical characteristics of the patients were not statistically different after propensity matching, except for CCS angina class III and era of surgical intervention (Table 3). Two or 3 arterial grafts were protective for death (HR, 0.8; Figure 2); cardiac readmission (HR, 0.8; Figure 3), including the primary diagnosis of myocardial infarction (HR, 0.8); and the composite outcome (HR, 0.9; Figure 4). There was no difference in revascularization rates between groups (Figure 5). It was found that low- to high-risk patients experienced outcome benefits with 2 or 3 arterial grafts related to cardiac readmission rates compared with 1 arterial graft (Table 4). It appeared the main benefit of 2 or 3 arterial grafts for low- to moderate-risk patients was in avoiding readmissions for unstable angina and myocardial infarction (Table 4). In high-risk patients the benefit of multiple arterial grafts was lower rates of readmission for congestive heart failure (Table 4).

Discussion

There have been many reports that have suggested that bilateral ITA bypasses compared with single arterial bypass might confer improved survival and freedom from nonfatal cardiac events.¹¹⁻¹³ However, currently accepted best practice only includes the use of a single left ITA-to-left anterior descending (LAD) artery bypass.^{2,8,14} This reflects the practices in our region, where multiple (>1) arterial grafting has only recently gained modest popularity. Our study was able to demonstrate at a population level in the province of Ontario that there appears to be a decreased risk of cardiac readmission, mortality, and composite outcome for those receiving 2 versus 3 arterial grafts versus those receiving 1 arterial graft. The benefits of 2 versus 3 arterial grafts in terms of lower rates of repeat cardiac readmission and mortality were evident in patients with a low to high operative risk. Our observations in terms of survival are similar to the benefits described through systematic review of the best available cohort studies.¹² In contrast to previous work, our study did not show that repeat revascularization rates improved with the use of multiple arterial grafts.⁴ Furthermore, our study did not show that 3 arterial grafts conferred further outcome advantages compared with 2 arterial grafts.

TABLE 3. Characteristics of propensity-matched patients (n = 5491 matched pairs) with 2 or 3 arterial grafts versus those with 1 arterial graft

Characteristic	One arterial graft	Two or 3 arterial grafts
Female sex	11%	11%
Era		
1991-1994*	15%	16%
1995-1998	33%	34%
1999-2001*	52%	50%
Age		
<60 y	59%	40%
60-69 y	28%	27%
70-79 y	12%	12%
≥80 y	1%	1%
Triage status		
Elective	48%	50%
Urgent	45%	43%
Emergency	7%	7%
Comorbidity		
Diabetes	21%	21%
Dialysis	0.7%	0.4%
Peripheral vascular disease	8%	8%
Cerebrovascular disease	6%	6%
Chronic obstructive pulmonary disease	7%	7%
Cardiac status		
Congestive heart failure	9%	9%
Previous CABG	1.9%	2.3%
Grade 3 left ventricular function	13%	13%
Grade 4 left ventricular function	1.6%	1.8%
CCS III*	38%	40%
CCS IV	40%	40%
Left main	18%	18%
Two vessel with PLAD and 3-vessel CAD	60%	60%
No. of total grafts		
1	0.6%	0.7%
2	18%	19%
3	39%	39%
≥4	42%	41%
Income quintile†		
1	18%	17%
2	18%	18%
3	20%	20%
4	22%	22%
5	21%	21%

CABG, Coronary artery bypass grafting; CCS, Canadian Cardiovascular Society Angina Class; PLAD, proximal left anterior descending coronary artery disease; CAD, coronary artery disease. *Not balanced between groups despite propensity matching ($P < .05$). †Income quintile 1 is the lowest quintile of income flagged by enumeration area.

Figure 2. Freedom from death after coronary artery bypass grafting (CABG) for those with 2 or 3 arterial grafts versus propensity-matched patients with 1 arterial graft in Ontario (1991-2001).

Figure 4. Freedom from all cardiac events and death after coronary artery bypass grafting (CABG) for those with 2 or 3 arterial grafts versus propensity-matched patients with 1 arterial graft in Ontario (1991-2001).

It is interesting to see that certain high-risk patient groups in our cohort were less likely to receive arterial grafts, including women, diabetic individuals, and those with moderate or severe angina and left ventricular dysfunction. It is thought that high-risk subgroups could potentially derive the most benefit from multiple arterial grafting. For example, it has been shown that women experience outcome benefits from 2 arterial grafts similar to those observed in men.¹⁵ In addition, there is evidence to show that the use of multiple arterial grafts is safe in diabetic patients and might be associated with improved survival and event-free survival.^{16,17}

Our study found that the low- to moderate-risk patients who received 2 arterial grafts obtained the most significant outcomes benefits in terms of freedom from cardiac events, specifically unstable angina and myocardial infarction. High-risk patients also derived benefit from 2 or 3 arterial

grafts, as evidenced by lower rates of readmission for congestive heart failure.

Although our study did not demonstrate that 3 arterial grafts conferred any further advantage to patients, it is important to note that our data only provided midterm outcomes for this group. It might be that longer follow-up could demonstrate differences in the durability of graft patency and an ensuing reduction in cardiac morbidity. This might also relate to the fact that surgeons in our region are early in their use and experience with multiple arterial grafting.

The strengths of our study include the fact that it is population based, and we did have complete outcomes follow-up on all patients as a result of available administrative databases. We were also able to efficiently match

Figure 3. Freedom from cardiac readmission and death after coronary artery bypass grafting (CABG) for those with 2 or 3 arterial grafts versus propensity-matched patients with 1 arterial graft in Ontario (1991-2001).

Figure 5. Freedom from repeat revascularization and death after coronary artery bypass grafting (CABG) for those with 2 or 3 arterial grafts versus propensity-matched patients with 1 arterial graft in Ontario (1991-2001).

TABLE 4. Cox hazards ratios of propensity-matched pairs by tertile of operative risk (predicted 30-day mortality risk)

Tertile of operative risk	Outcome	Hazard ratio (95% CI)	N (pairs)
Two or 3 vs 2 arterial graft Low predicted risk	Death	0.9 (0.62-1.21)	2421
	Cardiac readmission	0.7 (0.62-0.85)*	
	Unstable angina	0.8 (0.65-0.90)*	
	Myocardial infarction	0.7 (0.53-0.88)*	
	Congestive heart failure	0.8 (0.59-1.04)	
	Repeat revascularization	0.8 (0.65-1.05)	
	Composite	0.8 (0.65-0.88)*	
Moderate predicted risk	Death	0.9 (0.68-1.20)	1600
	Cardiac readmission	0.8 (0.64-0.89)*	
	Unstable angina	0.8 (0.67-0.95)*	
	Myocardial infarction	0.8 (0.64-1.03)	
	Congestive heart failure	0.8 (0.64-1.04)	
	Repeat revascularization	1.0 (0.78-1.26)	
	Composite	0.8 (0.68-0.92)*	
High predicted risk	Death	0.8 (0.61-1.01)	940
	Cardiac readmission	0.7 (0.62-0.89)*	
	Unstable angina	0.8 (0.67-1.00)	
	Myocardial infarction	0.9 (0.67-1.09)	
	Congestive heart failure	0.8 (0.61-0.94)*	
	Repeat revascularization	0.9 (0.69-1.10)	
	Composite	0.8 (0.64-0.92)*	

CI, Confidence interval. *Significantly different between groups ($P < .05$).

patients by propensity scores in each of the groups of interest, and most variables were balanced, indicating a relatively robust adjustment for case mix.

The limitations of our study include the fact this was a retrospective observational study, which partially required the use of administrative data to identify the arterial graft use (billing codes). These data did not distinguish ITA grafts from other arterial grafts, such as radial artery grafts. This might have diluted the observed outcomes advantages of arterial grafting and specifically the use of the ITA as a preferred option for a second arterial bypass. We had pre-operative clinical data; however, these did not include all operative variables. Despite this, the fact remains that large randomized trials are currently not available to fully understand the midterm to long-term outcomes of such grafting strategies, and thus observational studies are crucial in helping to further understand what is optimal for patients.

Conclusion

Although current guidelines encourage only the use of left ITA–LAD artery bypass, our data suggest that perhaps the use of a second arterial graft might be important in improving fatal and nonfatal cardiac event rates in all operative risk categories. We recognize that the use of multiple arterial grafting strategies is not widespread in our region. It also appears that there might be a disparity in higher-risk patients receiving fewer arterial grafts, despite past evidence to suggest potential outcomes benefits. We hope to highlight

these issues and encourage multiple arterial grafting strategies in our region.

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Discussion

Dr Colleen Sintek (Los Angeles, Calif). I congratulate Dr Guru and her coauthors on this large retrospective study comparing outcomes of patients undergoing isolated CABG based on the number of arterial grafts performed. The manuscript that I was sent and the abstract are somewhat different from the data that were presented today, but I think the conclusions are still similar.

You found that 2 arterial grafts are better than 1 graft in terms of death, repeat revascularization, and cardiac readmission rates for the low-risk and the moderate-risk patients, but you did conclude that 3 arterial grafts conferred no additional benefit. The advantage of 2 over 1 arterial graft is now widely accepted, but it was difficult to prove, and this is because the time-honored left ITA–LAD artery plus saphenous vein combination has very good outcomes during the first 10 years postoperatively. Therefore, to show improved outcomes with 2 arterial grafts, a very large sample size is needed and those patients must be observed for a relatively long time. Your study included more than 1000 patients with 3 arterial grafts, but the average follow-up was around 4 years. Therefore, your finding that 3 is not better than 2 may be premature.

It is disappointing that you were unable to differentiate arterial conduit type and target vessels. The studies that have demonstrated the superiority of 2 arterial grafts over 1 graft have focused on 2 arterial grafts to major left coronary branches, in other words, to the LAD and an obtuse marginal branch of the circumflex. If many of your patients with 3 arterial grafts had arterial conduits placed to only one major left coronary system, for instance, a graft to the LAD and 2 diagonal branches, rather than grafting say the LAD, obtuse marginal, or right coronary artery with arterial conduits, then the outcomes that you looked at might be quite different.

Finally, as you stated, the use of arterial grafts was far from uniform among the 8 hospitals that you studied. In fact, as shown in your manuscript, only 2 hospitals had more than 10% of patients

receiving 2 arterial grafts and only 1 had a sizable 3 arterial graft group. This raises the possibility of significant differences in individual surgeon experience levels using multiple arterial grafts that could negatively affect the results of the patients receiving 2 and especially 3 arterial grafts.

Did you look separately at the data from hospital 8, the hospital with the large number of patients receiving 3 arterial grafts? If you did not, does your propensity model account for the variables for individual surgeons?

Dr Guru. Thank you for these very relevant comments. Hospital 8 was a new program starting cardiac services in 2000-2001 consisting primarily of surgeons from another established hospital that also had a significant proportion of multiple arterial grafts. The data for hospital 8, therefore, only represent recent activity. I did include hospital variables within my propensity score because institution-specific practices influence selection biases in choosing which patient gets one versus more arterial grafts, and that needed to be adjusted for in the outcomes. I hope that this accounted for the variation in utilization. Certainly our region does not appear to be experienced with multiple arterial grafting. Only a couple of institutions have taken this on as their preferred way of doing the procedure.

Dr Sintek. I think that you answered my last question in the conclusion, but just so you can reiterate: Do you think that your study, which did not show a benefit of a third graft, should discourage cardiac surgeons from performing more than 2 arterial grafts or complete arterial revascularization in their patients?

Dr Guru. I definitely do not think so. I think all your comments are relevant. Certainly our study was underpowered to address whether a third arterial graft is beneficial from a follow-up standpoint, as well as from a numbers standpoint. Three arterial graft CABG was the smallest group we had. We did not have clinical data looking at where the distal targets were and the type of arterial graft used, and that information could greatly influence whether 3 arterial grafts are shown to be in fact better than 2 grafts.

Dr Guru. Unfortunately I do not have the type of arterial grafts used in our data bases, but we did survey the surgeons. Essentially it seems to be a 50:50 split between ITA and radial artery as the next choice for an arterial graft after the left ITA–LAD anastomosis. This may not be accurate, as we observed the overall self-reported rates of multiple arterial graft use did not correspond with the proportion of multiple arterial graft use measured in the actual data base.

Dr Guru. I didn't have the type of arterial graft used in any of the data bases that I had available to analyze.

Dr John Mitchell (Provo, Utah). Were your radial artery harvests done endoscopically or open? Postoperatively, how were you managing the radials medically?

Dr Guru. There really are only 2 institutions in Ontario that used radial arteries frequently, likely due to the randomized trial on this subject that was completed in our region, the Radial Artery Patency Study. In terms of endoscopic harvest in Ontario, we have limited resources and it would be unusual for endoscopic harvests to be completed during the study time period.

To address the second question in terms of medical therapy, there are guidelines within that trial that used calcium channel blockers up to 3 months after the operation to ensure that spasm did not occur. I think a majority of surgeons follow this practice, but I don't have the data.