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Background. **The second best conduit for coronary artery bypass graft surgery (CABG) is unclear. We sought to determine if the use of a second arterial conduit, the radial artery (RA), would improve long-term survival after CABG using the left internal thoracic artery (LITA) and saphenous vein (SV).**

Methods. **We compared the 14-year outcomes in propensity-matched patients undergoing isolated, primary CABG using the LITA, RA, and SV versus CABG using the LITA and only SV. In all, 826 patients from each group had similar propensity-matched demographics and multiple variables. The primary endpoint was all-cause mortality obtained using the Social Security Death Index.**

Results. **Perioperative outcomes including in hospital mortality (0.1% for the RA patients and 0.2% for the SV patients) were similar. Kaplan-Meier survival at 1, 5, and 10 years was 98.3%, 93.9%, and 83.1% for the RA group versus 97.2%, 88.7%, and 74.3% for the SV group (log rank, p = 0.0011). Cox proportional hazards models showed a lower all-cause mortality in the RA group (hazard ratio 0.72, confidence interval: 0.56 to 0.92, p = 0.0084). Ten-year survivals showed a 52% increased mortality for the SV patients (25.7%) versus the RA patients (16.9%; p = 0.0011). For symptomatic patients, RA patency was 80.7%, which was not different than the LITA patency rate of 86.4% but was superior to the SV patency rate of 46.7% (p < 0.001).**

Conclusions. **Using the LITA, SV, and a RA conduit for CABG results in significantly improved long-term survival compared with using the LITA and SV. The use of two arterial conduits offers a clear and lasting survival advantage, likely due to the improved patency of RA grafts. We conclude that RA conduits should be more widely utilized during CABG.**

(Ann Thorac Surg 2010;90:1165–72)

The left internal thoracic artery (LITA) is the critical conduit during coronary artery bypass grafting (CABG). Loop and colleagues [1] demonstrated superior long-term survival of patients receiving a LITA to the left anterior descending artery rather than a saphenous vein (SV) graft due to improved late patency of the LITA. Bilateral internal thoracic artery (ITA) grafting improves survival compared with LITA only CABG [2, 3]. Harvesting the right internal thoracic artery (RITA), however, results in an increased incidence of sternal wound infections in diabetic patients and in obese patients, as well as in patients with chronic obstructive pulmonary disease, a growing proportion of patients undergoing surgery [4]. The RITA is also frequently used as a free or T graft owing to its limitations reaching target arteries as an in situ graft. These drawbacks have resulted in only a 4% use of bilateral ITA CABG as reported in The Society of Thoracic Surgeons (STS) database [5].

The radial artery (RA) is an excellent alternative to the RITA [6]. It is readily harvested endoscopically [7] while the LITA is taken down. It easily reaches any vessel on the heart and is a better size match to the native coronary arteries than the SV. Sequential or Y grafting increases the number of arterial grafts per patient. There are several studies showing the benefits of RA grafts compared with SV grafts in CABG patients receiving a LITA graft [8–10]. Despite very encouraging short and intermediate outcomes, RA grafting is used in only 9% of patients undergoing CABG as noted in the STS database (5). Thus, the vast majority of patients presently undergoing CABG in the United States receive only one arterial graft, the LITA, and SV grafts.

We reviewed our 14-year experience with RA grafting to determine if the addition of a second arterial conduit, the RA, would improve long-term survival after CABG using the LITA and SV.

Patients and Methods

Patients

We performed a retrospective study of 4,271 consecutive patients who underwent isolated, primary CABG from January 1995 to January 2009. In all, 2,711 patients re-

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ceived a LITA graft and SV as needed; and 1,560 patients received a second arterial conduit, the RA, in addition to the LITA and SV. The primary indications for using a RA graft were age less than 65 years and a target vessel stenosis of at least 70%. Unavailable or unsuitable SV accounted for our RA use in older patients. Initially, the RA was employed in one third of patients but this has recently increased, so that now RA grafts are used in two thirds of our CABG patients. Hemodialysis was considered a strong contraindication for RA harvest due to concern for the need for possible upper limb dialysis access.

The Division of Cardiac Surgery at the Beth Israel Medical Center maintains a prospectively collected database on all patients undergoing cardiac surgery as part of the New York State, Department of Health, Cardiac Surgery Reporting System. All data are reported to the State and also are maintained in a separate database using ACCESS. This study was approved by the Institutional Review Board, which waived written informed consent.

Surgical and Radial Artery Harvesting Technique

The CABG was performed on pump using cold blood cardioplegic arrest. Distal and proximal anastomoses were performed during a single period of aortic cross clamping. The RA grafts were used as aortocoronary bypasses. Proximal anastomosis to another RA, SV, or very rarely, LITA was employed only when lack of RA length or aortic disease precluded direct aortic anastomosis. Off-pump procedures were performed in 3.1% of all patients (4.1% of the SV patients and 1.3% of the RA patients) owing to an unclampable or heavily diseased ascending aorta. None of the propensity-matched patients had off-pump surgery. Before 1999, the RA was harvested using an open no-touch technique. As we gained experience in endoscopic saphenous vein harvesting, endoscopic RA harvesting using the harmonic scalpel has been used exclusively since 2000 with no conversions to an open technique. Diltiazem is administered by intravenous infusion after induction of anesthesia and continued until the first postoperative day, when oral nitrates or diltiazem are substituted, and continued wherever possible for at least 6 months.

Intraoperative Allen's test and pulse oximetry were used to confirm adequate collateral blood flow to the hand. Less than 2% of screened RA was not harvested. No postoperative hand ischemia has been detected. A rare harvested RA had to be discarded because of unsuspected intraluminal disease. After removal, the radial artery was cannulated at the proximal end and placed in a solution of 1% papaverine mixed with the patients heparinized venous blood, which contains diltiazem.

Propensity Matching

Propensity score matching was used to select matched pairs between the radial and the vein groups to minimize differences between these two groups and overcome the confounding effects of patient selection [11]. We conducted propensity matching on the following variables: age, sex, year of surgery, surgeon, ejection fraction, hypertension, transmural myocardial infarction, stroke, carotid disease, peripheral vascular disease, hemodynamic instability at time of procedure, current congestive heart failure, chronic obstructive pulmonary disease, extensive ascending aortic atherosclerosis, extent of coronary artery disease, number of grafts per patient, diabetes mellitus, and increased creatinine level of more than 2.5 mg/dL. Five RA and 82 SV patients on hemodialysis were excluded from the study. We used these variables as predictors in a logistic regression model—with radial artery use as the predictor variable. The output of this logistic regression model generated propensity scores, differing by no more than 1%, which were used to select the matched pairs from RA and SV patients. Patients who received surgery between January 1995 and January 2009 were included. After excluding the 87 hemodialysis patients and 176 patients with missing extent of coronary artery disease data, 4,271 patients remained and 1,652 patients were generated as a result of propensity matching: 826 RA patients and 826 SV patients.

Statistical Methods

Statistical analysis was performed with the SAS system (SAS Institute, Cary, NC). Continuous variables were expressed as mean and standard deviation. Categorical variables were expressed as percentages. Dichotomous variables were analyzed using the χ^2 test and Fisher's exact test, and continuous variables were analyzed using the *t* test. The primary endpoint was all-cause mortality obtained using the Social Security Death Index, which was searched in January 2009. Overall survival was estimated by Kaplan-Meier survival method. The log-rank test was used to assess differences in survival between groups. The Cox proportional hazards regression model was used to determine independent predictors of survival. Modeling was done using backward elimination. Variables with p values less than 0.05 were retained in the final model. Hazard ratios and 95% confidence intervals are presented.

Results

Patient Data

Table 1 summarizes the preoperative risk factors, the operative data, and the postoperative complications for all RA and SV patients. Briefly, the prematched RA patients were younger (mean age 57.1 years versus 68.1), mostly male (82.7% versus 65.6%), and had fewer comorbidities. The extent of coronary artery disease was more extensive in the RA group. Grafts per patient averaged 3.8 for RA patients, with an average of 2.3 arterial grafts. The SV patients had an average of 3.4 grafts per patient, with an average of 1.0 arterial graft per patient. Eight percent of the patients had bilateral RA grafts, and 7% of the patients had bilateral ITA grafts. Thirty-five percent of the RA patients received more than 2 arterial grafts,

Table 1. Comparison of Radial Artery and Saphenous Vein Patients

	Before Propensity Matching			After Propensity Matching		
	Radial n = 1,560	Vein n = 2,711	*p* Value	Radial n = 862	Vein n = 862	*p* Value
All-cause mortality	9.5%	30.7%	<0.0001	12.8%	19.0%	0.0006
Mean age, years ± SD	57.1 ± 8.5	68.4 ± 9.3	<0.0001	60.8 ± 8.1	60.8 ± 9.2	0.8554
Male	82.7%	65.6%	<0.0001	76.5%	78.5%	0.3460
Body mass index ± SD	29.0 ± 5.8	28.0 ± 5.7	<0.0001	29.0 ± 5.3	28.6 ± 5.2	0.1151
Hispanic	21.0%	20.0%	0.4196	21.8%	22.8%	0.4763
Race						
White	68.5%	69.1%		70.6%	64.3%	
African American	10.7%	13.0%		10.1%	14.3%	
Other	20.8%	17.9%		19.4%	21.4%	
Mean EF ± SD	48.2 ± 11.4	46.1 ± 13.2	<0.0001	48.3 ± 11.8	47.7 ± 13.2	0.2719
Years since surgery ± SD	7.7 ± 4.0	8.7 ± 3.7	<0.0001	8.0 ± 4.	8.2 ± 3.8	0.5520
Transmural MI	32.9%	36.6%	0.0178	32.1%	34.0%	0.4027
Stroke	4.6%	6.8%	0.0035	5.5%	5.9%	0.6710
Carotid disease	5.1%	14.2%	<0.0001	6.7%	7.6%	0.4447
Femoral PVD	5.5%	8.7%	<0.0001	6.7%	8.6%	0.1381
Hemodynamics unstable	1.2%	1.8%	0.1179	1.1%	1.3%	0.6527
Current CHF	3.2%	8.8%	<0.0001	5.0%	5.0%	1.0000
COPD	18.1%	32.5%	<0.0001	21.7%	20.1%	0.4314
Ascending aortic disease	3.3%	8.7%	<0.0001	4.6%	5.1%	0.6466
Diabetes mellitus	35.3%	38.3%	0.0533	36.4%	38.3%	0.4455
Creatinine >2.5 mg/dL	0.8%	2.4%	0.0002	1.2%	1.8%	0.3136
Hypertension	64.5%	74.3%	<0.0001	68.9%	69.0%	1.0000
Coronary vessel disease						
Triple	82.9%	77.3%	<0.0001	81.4%	78.5%	0.1406
Double	13.3%	15.6%	0.0409	13.9%	15.3%	0.4433
Single	3.1%	5.7%	0.0002	3.6%	5.5%	0.0763
Left main disease	27.4%	31.9%	0.0017	28.8%	29.2%	0.8708
Mean cross-clamp time, min ± SD	71.1 ± 23.3	62.0 ± 21.0	<0.0001	70.3 ± 27.3	64.8 ± 19.6	<0.0001
Mean perfusion time, min ± SD	93.9 ± 32.1	85.4 ± 31.8	<0.0001	93.4 ± 38.5	87.7 ± 26.4	0.0005
Grafts/patient ± SD	3.8 ± 0.9	3.4 ± 0.9	<0.0001	3.6 ± 0.9	3.6 ± 1.0	0.8738
Priority						
Elective	23.0%	21.2%	0.0149	22.4%	24.5%	0.3050
Urgent	70.8%	70.4%		71.9%	67.17%	
Emergent	6.2%	8.5%		5.7%	8.5%	
Operative mortality	0.1%	1.9%	<0.0001	0.1%	0.2%	1.0000
Permanent stroke	0.9%	2.0%	0.0059	1.2%	1.7%	0.2938
Perioperative MI	1.0%	1.1%	0.6548	0.9%	1.2%	0.4645
Sternal wound infection	1.1%	1.5%	0.2506	1.7%	1.3%	0.5455
Septicemia	0.9%	2.7%	<0.0001	1.2%	1.2%	1.0000
Reoperation for bleeding	1.7%	2.3%	0.1694	1.5%	1.7%	0.6926
Respiratory failure	1.8%	4.7%	<0.0001	2.2%	3.2%	0.2215
Renal failure	0.7%	2.3%	0.0001	1.2%	0.7%	0.3150

CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; EF = ejection fraction; MI = myocardial infarction; PVD = peripheral vascular disease.

mostly by using the RA as a sequential or Y graft. Our goal was to achieve complete arterial revascularization of the left coronary artery system. Saphenous vein grafts were most frequently used to bypass the right coronary system in this unmatched RA cohort of patients. Outcomes were better (RA group operative mortality 0.1% versus SV group 1.9%, $p < 0.0001$), and major complications fewer (RA stroke, renal, and respiratory failure rates of 0.9%, 0.7%, and 1.8% versus SV rates of 2.0%, 2.3%, and 4.7%; $p = 0.0059$, $p < 0.0001$, and $p < 0.0001$, respectively).

Long-term Kaplan-Meier survival was significantly improved (82.9% for RA patients versus 55.1% for SV patients at 12 years; log rank test, $p < 0.0001$; Fig 1).

Table 1 also shows the similar demographics and risk factors for the propensity-matched patients. The cross-clamp time and perfusion time were each 6 minutes longer in the RA group ($p < 0.0001$). There were more SV patients undergoing emergent (the same day as cardiac catheterization) CABG, but more RA patients underwent urgent (during the same hospitalization) CABG. Average number of grafts per patient was 3.6 in both the RA and in the SV matched patients.

Propensity-Matched Patient Outcomes

In-hospital or 30-day mortality was very low among the propensity-matched patients (1 RA death [0.12%] versus 2 SV deaths [0.24%]; Table 1). Postoperative complication rates were also similar in the matched groups. Long-term survival for the propensity-matched patients is shown in Figure 2. Kaplan-Meier estimated survival at 10 years was 83.1% for the RA patients versus 74.3% for the SV patients ($p = 0.0011$). Thus, the corresponding 0- to 10-year mortality rate was 52% higher for the SV patients.

Table 2 shows the results of Cox regression modeling. Radial artery use was an independent predictor of decreased mortality (hazard ratio 0.715, $p = 0.0084$). Older age, peripheral vascular disease, extensive ascending aortic disease, stroke, diabetes, chronic obstructive pulmonary disease, and decreased left ventricular function were independent predictors of increased mortality.

Long-term follow-up was similar for RA matched patients (7.0 years; range, 0.1 to 13.8; median 7.7) and for SV matched patients (6.8 years; range, 0.2 to 14; median 6.8). There were a total of 106 late deaths (12.8%) in the RA group and 157 deaths (19.0%) in the SA group ($p = 0.0006$). The average time to death was 6.1 years for the RA patients and 5.2 years for the SV patients.

Kaplan-Meier estimated survival curves are shown in Figures 3, 4, and 5 for matched patients as a function of age, sex, and diabetes. There was a strong survival benefit for RA grafting among men (log rank test, $p = 0.0006$) and among patients less than 65 years of age (log rank test, $p = 0.0020$). Both diabetic patients (log rank, $p = 0.0562$) and nondiabetic patients (log rank test, $p = 0.0063$) benefited from RA grafting. Diabetic patients had a 57% increased 10-year mortality rate with SV grafting (36%) versus RA grafting (23%).

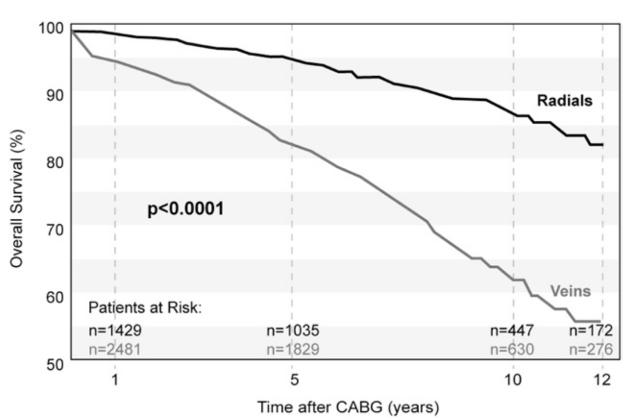

Fig 1. Comparison of unadjusted Kaplan-Meier survival for all patients ($p < 0.0001$, log rank test). CABG = coronary artery bypass graft surgery.

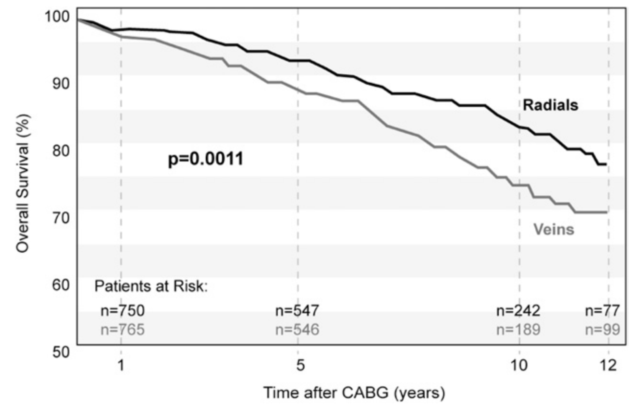

Fig 2. Comparison of Kaplan-Meier survival for propensity-matched patients ($p = 0.0011$, log rank test). CABG = coronary artery bypass graft surgery.

Radial Artery Patency

Two hundred and fifty-seven patients had symptom-driven cardiac catheterization 0.1 to 6.8 years after surgery at our institution. Only the initial catheterization was included in the analysis to avoid any effect on graft patency due to interventions. The mean time to catheterization was 4.3 years, with a median time of 3.4 years. Table 3 shows that for the RA patients, 151 patients had a total of 563 grafts (151 LITA, 3 RITA, 192 RA, and 217 SV grafts), or 3.7 grafts per patient, with 1.3 RA grafts per patient. For the 106 SV restudied patients, there were 335 grafts (106 LITA, 1 RITA, and 228 SV grafts), or 3.2 grafts

Table 2. Independent Predictors of 14-Year Mortality for 1,652 Matched Radial Patients and Saphenous Vein Patients

	Hazard Ratio	95% CI	*p* Value
Radial artery	0.715	(0.557, 0.918)	0.0084
Age, per year	1.053	(1.037, 1.069)	<0.0001
Stroke	1.761	(1.190, 2.606)	0.0047
Femoral PVD	1.630	(1.174, 2.263)	0.0035
COPD	1.364	(1.050, 1.772)	0.0201
Ascending aortic disease	1.888	(1.247, 2.858)	0.0027
Diabetes mellitus	1.872	(1.455, 2.409)	<0.0001
Ejection fraction	0.962	(0.969, 0.988)	<0.0001

Cox regression model to predict survival included age, sex, year of surgery, transmural myocardial infarction, stroke, carotid disease, femoral peripheral vascular disease (PVD), hemodynamic instability, current congestive heart failure, chronic obstructive pulmonary disease (COPD), extensive ascending aortic atherosclerosis, diabetes, creatinine more than 2.5 mg/dL, hypertension, number of grafts per patient, and surgeon.

CI = confidence interval.

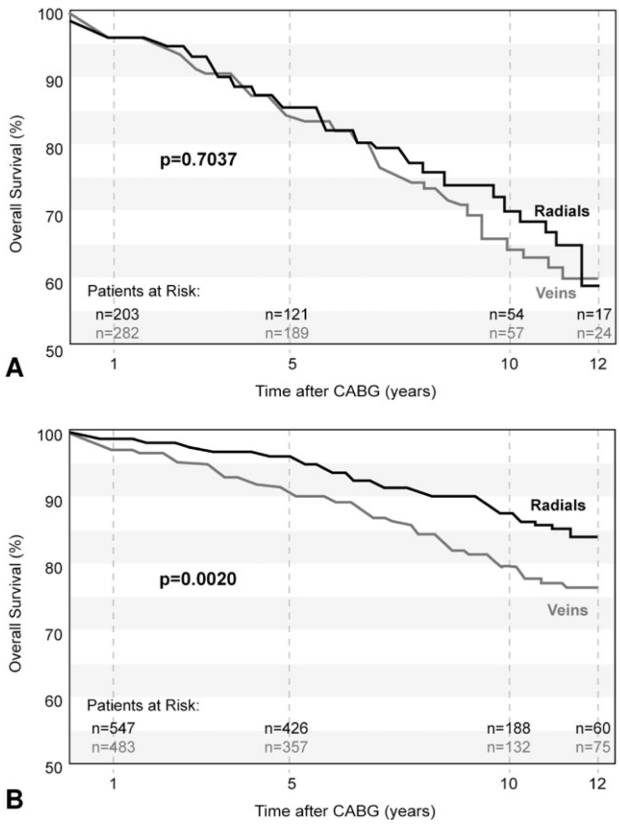

Fig 3. Comparison of Kaplan-Meier survival for propensity-matched patients (A) aged 65 years or more (p = 0.7037, log rank test) and (B) aged less than 65 years (p = 0.0020, log rank test). CABG = coronary artery bypass graft surgery.

per patient. In both the RA and the SV group, the LITA perfectly patent rate was superior to the SV patency rate (LITA 86.4% versus SV 46.7%, $p < 0.001$). There was no difference in the LITA and RA patency rates (86.1% versus 80.7%, $p = 0.24$). The RA patency was significantly better than the total SV graft patency (RA 80.7% versus SV 46.7%, $p < 0.001$).

For all restudied matched patients, the LITA had the lowest graft occlusion rate (LITA 4.2%, RA 12.5%, and SV 30.8%). This low failure rate of the LITA was significantly better than both RA ($p < 0.002$) and SV grafts ($p < 0.001$). The RA failure rate was better than the SV failure rate (12.5% versus 30.7%, $p < 0.001$).

Comment

Our series of 1,560 unmatched consecutive patients undergoing isolated, primary CABG using the LITA and the RA as the second conduit of choice over 14 years is the one of the largest reported. Radial artery grafting is clearly safe (operative mortality of 0.13%) and results in excellent long-term survival with 1-, 5-, 10-, and 12-year Kaplan-Meier survivals of 99%, 95%, 87%, and 83%, respectively. Several authors have reported intermediate survival after radial artery grafting. Zacharias and colleagues [9] found a 6-year survival rate of 92% for 1,292 patients, and Cohen and colleagues [8] reported a 96% 3-year survival for 478 patients. These intermediate results and our long-term findings provide strong support for RA grafting. However, the infrequent use of RA grafting suggests a lack of clearly defined advantages of RA versus SV grafting.

Our most important finding was that propensity-matched patients receiving RA conduits have significantly improved long-term survival compared with patients receiving SV conduits after CABG using the LITA. Two different statistical methods confirmed our finding. Using Cox multivariate modeling, LITA/RA CABG results in a 28% decrease in risk adjusted 14-year mortality compared with traditional LITA/SV CABG (Table 2). Use of RA was an independent and significant ($p = 0.0084$) predictor of improved survival in the propensity-matched groups. We also used Kaplan-Meier estimated survival curves to show significantly improved survival at 14 years using the RA (log-rank test, $p = 0.0011$; Fig 2). Our study confirms the findings of Zacharias and colleagues [9]. They found a 32% decrease in 6-year mortality for patients using RA grafting compared with a propensity-matched group of patients undergoing CABG using the LITA and SV. These combined results show

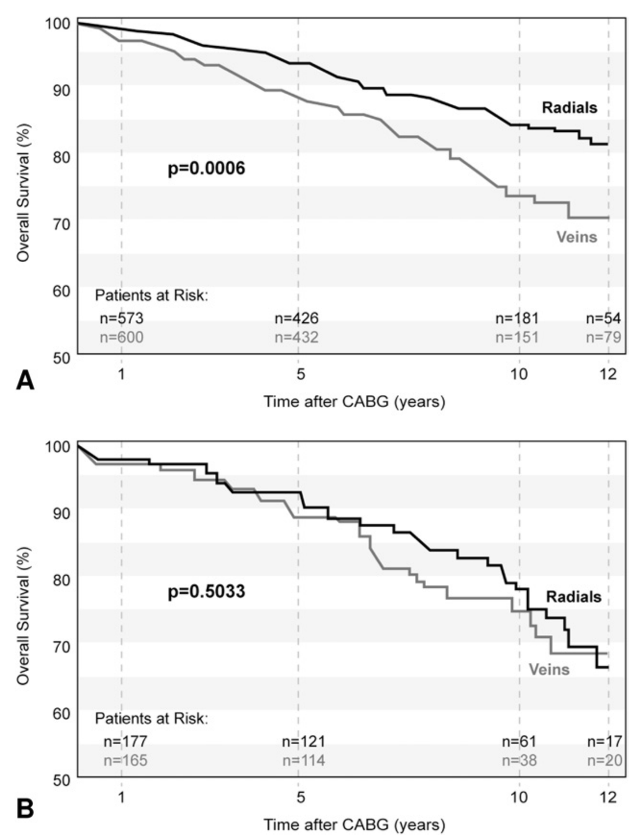

Fig 4. Comparison of Kaplan-Meier survival in propensity-matched (A) male patients (p = 0.0006, log rank test) and (B) female patients (p = 0.5033, log rank test). CABG = coronary artery bypass graft surgery.

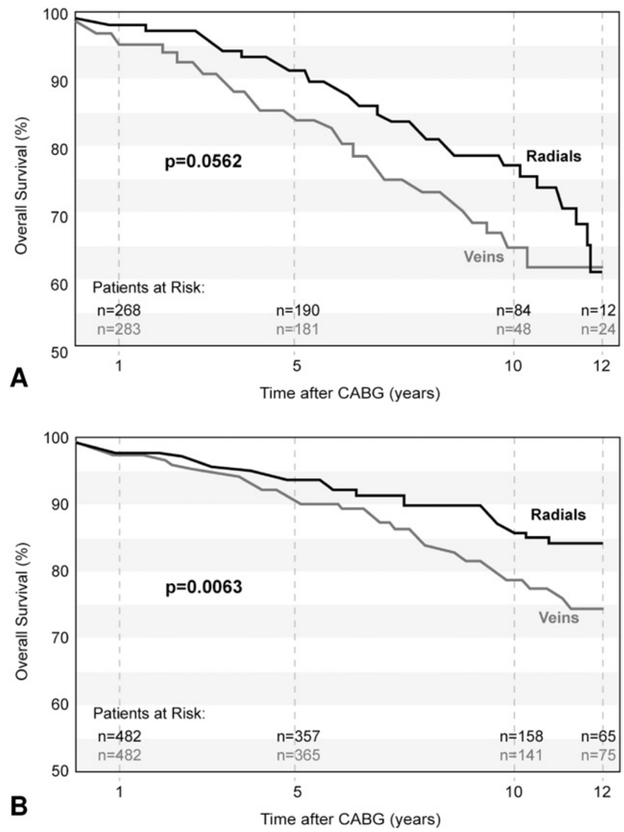

Fig 5. Comparison of Kaplan-Meier survival among propensity-matched (A) diabetic patients ($p = 0.0562$, log rank test) and (B) nondiabetic patients ($p = 0.0063$, log rank test). CABG = coronary artery bypass graft surgery.

that the radial artery is an important conduit resulting in improved long-term survival after CABG using the RA compared with using only SV.

The choice of the RA versus the RITA as the second arterial conduit is unsettled [12]. Caputo and investigators [13] found that the RA had a stronger protective effect than the RITA 18 months after CABG. Nasso and colleagues [14] confirmed that two arterial conduits are better than one, but that the choice of RA versus RITA did not affect the 2-year survival. Hayward and investigators [15] of the Radial Artery Patency and Clinical Outcome (RAPCO) trial reported equivalent clinical outcomes at 5 or more years in patients randomly assigned to receive either a RA or RITA to the largest target after the LAD. These results, the technical advantages of RA grafts, and our experience support the use of the RA as the second arterial conduit of choice.

Several ongoing studies, including the Radial Artery Versus Saphenous Vein Patency (RSVP) [16], the Radial Artery Patency Study (RAPS) [17], and the RAPCO [15] trials have all shown excellent patency rates of radial artery grafts. Desai and the RAPS investigators [17] found a 92% patency at 1 year in radial artery patients randomly assigned to either RA or SV bypass grafts. Collins and the RSVP investigators [16] reported a 5-year radial artery patency rate of 98% in patients randomly allocated to receive an RA or SV to a stenosed branch of the circumflex coronary artery. Buxton and the RAPCO investigators [18] found a 95% RA 5-year patency compared with a 100% RITA patency in a prospective randomized trial comparing these two conduits. Tatoulis and Buxton [19] recently reported their 10-year results with 1,108 RA angiograms, finding an 89% RA graft patency at an average of 4 years. For 425 radial arteries in place more than 5 to 7 years, the patency was 92% without any evidence of atherosclerosis.

We found an 80.7% RA patency rate compared with a 46.7% SV patency rate in 257 symptomatic patients ($p < 0.001$). Our radial artery patency findings are similar to the above protocol-driven results in asymptomatic patients. There was not a statistically significant difference in the patency rates of the LITA and RA (86% versus 80.7%, $p = 0.24$). This observed improved patency of the RA grafts compared with SV grafts likely results in the improved survival of patients receiving RA grafts.

The age of the patient and the degree of left ventricular dysfunction were important and expected predictors of mortality in the matched patients. Other significant independent predictors of mortality were the extent of associated pulmonary and vascular disease. Diabetes was an independent predictor of poorer long-term survival. Nonetheless, diabetic patients still benefit from RA grafting. We found a benefit (not quite statistically significant) compared with SV grafting (log-rank test, $p = 0.0562$; Fig 5). Singh and fellow RAPS investigators [20] found RA grafting to be protective in diabetic patients, and Zachar-

Table 3. Angiographic Results for 257 Symptomatic Patients

Angiographic Result	LITA	RA	RITA	SV
RA group, 151 patients	n = 151	n = 192	n = 3	n = 217
Perfectly patent	130 (86.1%)	155 (80.7%)	3 (100%)	98 (45.2%)
Patent with >50% disease	13 (8.6%)	13 (6.8%)	0	52 (24.0%)
Occluded	8 (5.3%)	24 (12.5%)	0	67 (30.9%)
SV group, 106 patients	n = 106		n = 1	n = 228
Perfectly patent	92 (86.8%)		1 (100%)	110 (48.2%)
Patent with >50% disease	11 (10.4%)		0	48 (21.1%)
Occluded	3 (2.8%)		0	70 (30.7%)

LITA = left internal thoracic artery; RA = radial artery; RITA = right internal thoracic artery; SV = saphenous vein.

ias and colleagues [9] found the survival benefits of RA grafting to be most profound in young diabetic patients with triple-vessel disease. However, in a subsequent report, these investigators were unable to demonstrate a survival benefit of RA grafting for diabetic patients [21]. We have found that diabetic patients' radial arteries occasionally have areas of minor calcification and thickening, but for the most part, are excellent conduits. Our experience and most of the available literature suggest that RA grafting likely improves long-term survival in diabetic patients and that any potential increased vasoreactivity in diabetic radial arteries (22) is not clinically significant. We also found a significant survival benefit for men and for patients less than 65 years of age (Figs 3 and 4).

Although our study is retrospective, the series represents a large, single-site, consecutive experience with standardized techniques. Preoperative, operative, and in-hospital postoperative data are derived from a mandatory, audited state database and recorded prospectively. Only isolated primary coronary bypass patients were analyzed. Survival data are derived from the Social Security Death Index and not from individual patient follow-up. Coronary angiography after surgery was not protocol driven, and we were able to capture only those patients who returned to our hospital for the angiogram. Comparisons between grafts to the circumflex and right coronary territories are not valid in our study because of the bias against using the RA to bypass the right coronary artery. Finally, although propensity matching is an excellent tool for comparing outcomes in different patient groups, it may not fully adjust for selection bias and patient heterogeneity.

Using the RA instead of the SV for CABG results in improved long-term survival of patients receiving a LITA to the left anterior descending artery. The RA is an excellent second choice of conduit to bypass the next most important target after the left anterior descending artery, so long as the target has a high-grade lesion. Our results suggest that RA grafting should be more widely utilized in CABG.

Furthermore, our results have important implications when deciding on the initial revascularization strategy for patients with multivessel disease. The surgical arms of the four highly selected, randomized, controlled studies comparing percutaneous coronary intervention and CABG include very few patients who received more than one arterial conduit [23]. None of the patients received radial arteries. Further studies are needed to define the survival advantages of CABG using multiple arterial grafting compared with percutaneous coronary intervention for patients with multivessel disease.

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INVITED COMMENTARY

Tranbaugh and colleagues [1] compare 10-year survival in two propensity-matched cohorts of patients (862 with a radial artery [RA] graft and 862 with a saphenous vein [SV] graft). The mean number of total grafts was 3.8 and 3.4, respectively, and for arterial grafts was 2.3 and 1.0, respectively. The main selection criteria for the use of RA grafts was age less than 65 years and a stenosis of at least 70% in the native coronary artery. At 10 years, Kaplan Meier estimated survival was 83% for the RA patients (n = 242) and 74% for the SV patients (n = 189); $p = 0.001$. Symptom-driven cardiac catheterization was performed in 257 patients at a mean 4.3 years with respective graft patencies of the internal thoracic artery, RA, and SV at 86%, 81%, and 47%, respectively ($p < 0.001$).

This study was conducted by a highly credible group, and it is particularly important because it is not only one of the largest reports in the literature on the use of the RA, but it also has one of the longest follow-ups. In particular, the authors should be congratulated on their excellent clinical outcomes with very low 30-day mortalities (0.12% for the RA group and 0.24% for the SV group).

However, can the marked difference in 10-year survival between the groups really be attributed to the RA rather than the SV graft? There are three possible explanations for the findings by this group of authors [1]:

1. As indicated by the authors, there is good evidence in the literature of superior patency of RA in comparison with SV when used in coronary vessels with at least a 70% stenosis, and this may well explain, at least in part, the difference in survival.
2. However, as the patients were not part of a randomized trial, another obvious possibility is that the difference in outcome may be due to known confounding factors that can affect survival, such as differing baseline characteristics. Conversely, however, the patient groups were very well matched with respect to the most obvious confounding factors, such as age, gender, diabetes, severity of coronary artery disease, and ventricular function, as well as the presence of other comorbidities including previous stroke, concomitant carotid or peripheral vascular disease, renal impairment, and chronic obstructive pulmonary disease.
3. The results are due to unknown confounding factors or the "play of chance."

The major clinical relevance of this article is that it reinforces the claim that the use of the RA is clinically safe and is a clarion call for the routine use of more arterial grafts. The reluctance to use more arterial grafts in the face of ever-improving stent techniques has undoubtedly contributed to the loss of patients requiring revascularization from surgery to stents. If the current results were to be replicated in other large cohorts of patients, then they would strengthen the possibility that the use of an RA may indeed be almost as beneficial or possibly even superior to the use of a second internal thoracic artery (ITA) [2], but without the increased risk of sternal wound problems, particularly in diabetic patients. The 1-year outcomes of a randomized trial of more than 3,000 patients randomized to single or bilateral ITA [3] with 10-year follow-up will be presented later this year. If indeed a second ITA graft offers survival benefit in comparison with a single ITA graft, then the results presented in the current article would strongly support the need for a randomized trial of an RA or a second ITA as the best second arterial conduit for routine clinical practice.

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Radial Artery Conduits Improve Long-Term Survival After Coronary Artery Bypass Grafting

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