

21-Year Survival of Left Internal Mammary Artery–Radial Artery–Y Graft



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ABSTRACT

BACKGROUND In 1999, Royse et al. reported on the left internal mammary artery, radial artery, Y-graft technique (LIMA-RA-Y), which achieves total arterial revascularization (TAR). However, the most common coronary reconstruction remains LIMA and supplementary saphenous vein grafts (LIMA + SVG).

OBJECTIVES The goal of this study was to conduct a survival comparison of LIMA-RA-Y versus the conventional LIMA + SVG.

METHODS Of the original 464 LIMA-RA-Y patients reported (1996 to 1998), 346 were from the Royal Melbourne Hospital. Survival at June 2017 was compared with a group of 534 patients from 1996 to 2003 from the same institution who received LIMA + SVG, or 5,800 patients who received TAR with different grafting configurations. Propensity score matching (PSM) was performed with 1:1 matching using 26 variables. Comparisons used Kaplan-Meier (KM) and Cox proportional hazards methods. LIMA-RA-Y was compared with LIMA + SVG in which all non-left anterior descending artery grafts were performed with either composite RA or aorta-coronary SVG with no use of right internal mammary artery. We also conducted a comparison of LIMA-RA-Y versus TAR.

RESULTS Baseline characteristics of the LIMA-RA-Y group (n = 346) compared with LIMA + SVG (n = 534) after PSM (n = 232 pairs) did not differ (3.3 ± 0.8 grafts per patient). Survival was worse for LIMA + SVG in the unmatched groups (KM, $p < 0.001$) and for PSM groups (KM, $p = 0.043$; Cox proportional hazards ratio: 1.3; 95% confidence interval: 1.0 to 1.6; $p = 0.038$). Survival did not differ between LIMA-RA-Y and other TAR (n = 5,800) patients before, or after, PSM (n = 332 pairs).

CONCLUSIONS Use of LIMA + SVG has worse survival than LIMA-RA-Y in achieving total arterial revascularization. (J Am Coll Cardiol 2018;72:1332–40) © 2018 by the American College of Cardiology Foundation.

As best as can be established, ~90% to 95% of coronary artery bypass grafting (CABG) worldwide is performed according to the technique using left internal mammary artery (LIMA) with supplementary saphenous vein grafts (SVG) (i.e., LIMA + SVG). We consider this operation as the “world standard operation” for CABG. The accepted evidence is that SVG frequently develop atherosclerosis over time and the incidence of graft failure approximates 50% 10 years’ post-operation

(1–4). This is the primary mechanism for the late failure of CABG.

At Royal Melbourne Hospital, the radial artery (RA) has been used in >80% of patients undergoing CABG since 1997, which achieves total arterial revascularization (TAR) >80% (5). The rationale for using arterial conduits instead of SVG is based on the expected late freedom from progressive conduit atherosclerosis and failure in arterial grafts, thereby leading to higher late patency and higher freedom from late ischemic



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cardiac events (5–7). However, it is clear from the low rates of TAR worldwide that this rationale is not widely held by most surgeons.

The conventional view is that most arterial conduits fail due to competitive flow in the coronary artery when anastomosed to a moderately stenosed coronary artery lesion (8,9). This scenario is also considered to be the primary mechanism by which failure of arterial grafts does not lead to clinically significant ischemic events (i.e., the myocardium is not dependent on graft blood flow at the time of failure) because the native coronary artery provides an adequate blood supply. Ischemia in this territory may occur later due to progression in severity of that coronary lesion; thus, early failure of the arterial conduit may not lead to late protection from ischemia. However, in the case of SVG, late failure may lead to myocardial ischemia because the target myocardium is dependent on graft blood flow at the time of failure, leading to clinically significant events of myocardial infarction, recurrence of angina, or heart failure (10).

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Suturing the RA to the LIMA as a composite graft (LIMA-RA-Y) is a technique that maximizes the efficiency of using an arterial conduit. Its primary purpose is to reliably avoid use of SVG with fewer conduits than alternative reconstruction strategies. The LIMA is used to revascularize the left anterior descending artery (LAD) territory; and the RA is used to revascularize the circumflex and right coronary artery (RCA) territories (Central Illustration, Figure 1). The right internal mammary artery was not used but is an alternative method of reconstruction using LIMA-RIMA-Y; harvesting the second internal mammary artery could result in higher rates of mediastinitis, however.

The original 1999 technique series described 464 patients with a single mortality (0.2%) at 30 days, demonstrating feasibility of this operation as well as early safety (11). Actuarial survival was 98% at 36.1 months. The aim of the present study was to examine the late (>10 years) survival of LIMA-RA-Y patients with a contemporaneous group of LIMA + SVG patients subjected to propensity score matching (PSM). We also tested if the survival for LIMA-RA-Y differs from other TAR reconstruction techniques.

METHODS

The study was approved by the Melbourne Health Human Research Ethics Committee and the Australian Institute of Health and Welfare; informed

consent of the patient was waived. Of the 464 patients in the original paper (1996 to 1998) (11), 346 underwent their CABG surgery at the Royal Melbourne Hospital, and these subjects formed the follow-up group to ensure a single institution for all patients. During a contemporaneous time period (1996 to 2003), 534 patients from the same institution received LIMA + SVG. The groups underwent PSM (1:1), yielding 232 pairs (described in the Results). For the comparison with TAR during the same contemporaneous period from the same institution, 5,800 patients were included (after exclusion of the 346 LIMA-RA-Y patients), and PSM yielded 332 pairs. At the censor date, the study time frame post-operative was 13 to 21 years; thus, all surviving patients were in the “late period.” All patients were routinely prescribed statins post-operatively.

The primary outcome was all-cause mortality. These data were obtained from the Australian Institute of Health and Welfare national death registry, and the censor date was June 1, 2017.

Continuous data and categorical data in unmatched data were compared with Student’s 2-tailed *t*-tests and Fisher exact tests, respectively; paired Student’s *t*-tests and McNemar’s tests for paired samples were used in matched data. A Cox proportional hazards model (Cox) with multivariable (Figures 2 and 3) or univariable (Central Illustration, Figure 4) analysis was used to compare mortality between groups. These analyses were complemented with proportionality tests to check for the consistency of the hazard ratio in the time frame. Kaplan-Meier (KM) tests with stratified log-rank tests were used as appropriate. Significance was determined by *p* values < 0.05. Data were coded by using Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington) and analyzed by using SPSS IBM SPSS Statistics for Windows, version 23.0 (IBM SPSS Statistics, IBM Corporation, Armonk, New York) (12).

PSM was performed to mitigate possible selection bias at surgery and was calculated by using logistic regression of 26 variables with treatment assignment being the outcome. Matching was performed by using nearest neighbor (13) with a 1:1 ratio without replacement within a caliper of 0.05 of SD of propensity score logit. Strict matching between patients was done on patient sex. The variables included in the PSM analysis incorporated major cardiac risk factors (smoking, diabetes, hypercholesterolemia, hypertension, obesity, and family history of coronary

ABBREVIATIONS AND ACRONYMS

CABG = coronary artery bypass grafting

LAD = left anterior descending artery

LIMA = left internal mammary artery

LIMA-RA-Y = left internal mammary artery, radial artery, Y graft

LIMA + SVG = left internal mammary artery and supplementary saphenous vein graft

TAR = total arterial revascularization

PSM = propensity score matching

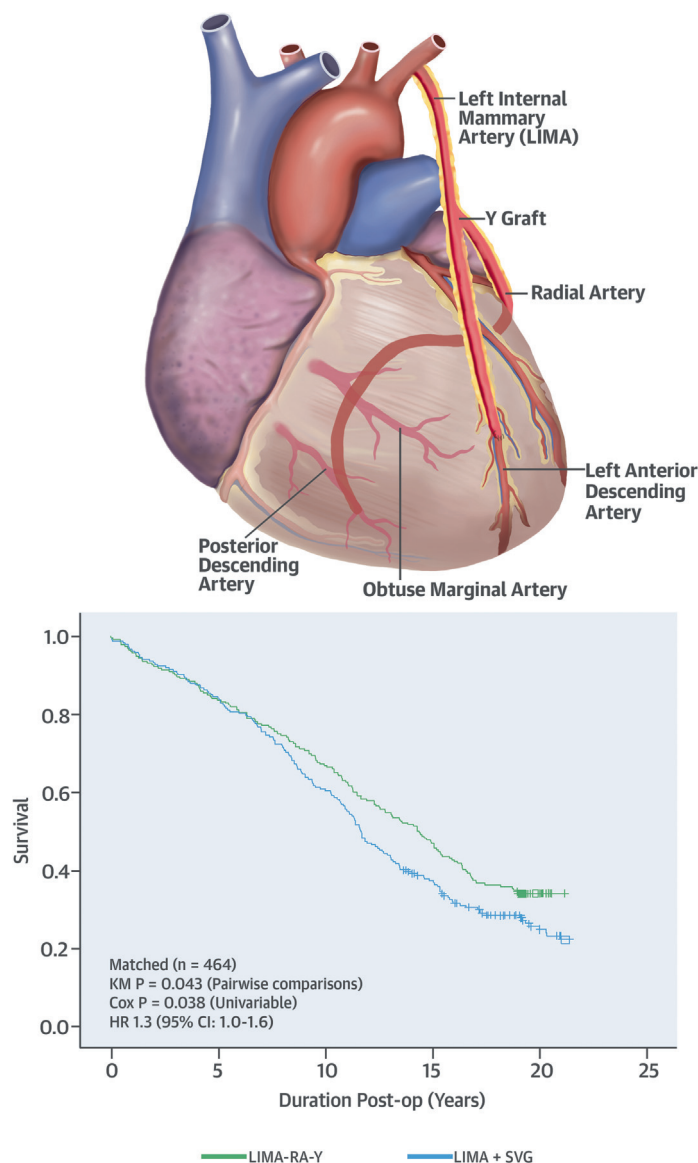
RA = radial artery

RCA = right coronary artery

SVG = saphenous vein graft

Y graft = composite graft between 2 or more conduits

CENTRAL ILLUSTRATION Left Internal Mammary Artery, Radial Artery, Y Graft Operation and Survival Curves



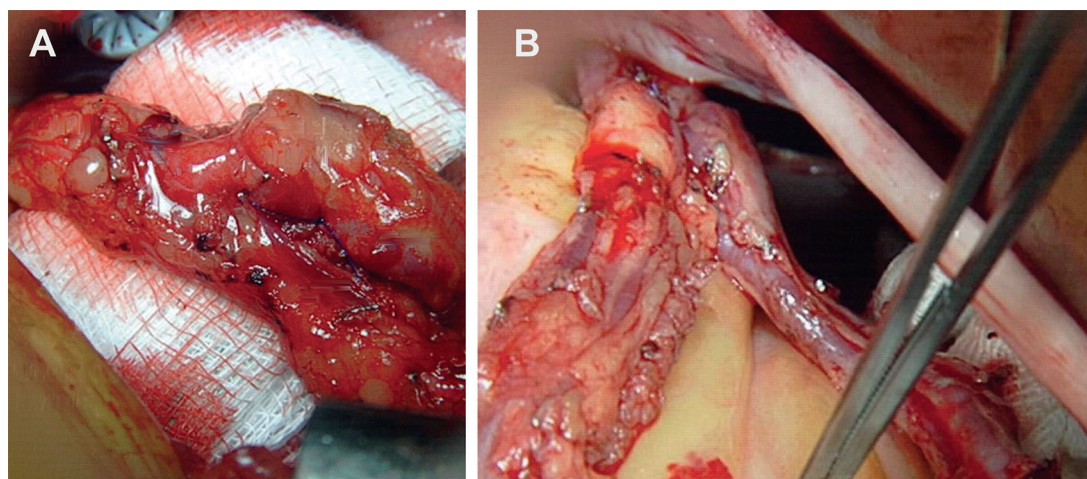
Royse, A.G. et al. *J Am Coll Cardiol.* 2018;72(12):1332-40.

(Upper panel) Left internal mammary artery, radial artery, Y-graft (LIMA-RA-Y) operation. The LIMA is used to revascularize the left anterior descending territory, and the composite radial artery (RA) graft is used to revascularize the circumflex and right coronary territories. Both LIMA and the left RA can be harvested simultaneously; avoidance of a second internal mammary artery may result in lower risk of mediastinitis than both internal mammary arteries being harvested. **(Lower panel)** Survival LIMA-RA-Y versus left internal mammary artery and supplementary saphenous vein graft (LIMA + SVG) (matched n = 464). Propensity score-matched survival up to 21 years after surgery shows significantly lower survival for the LIMA + SVG operation, with the hazard ratio (HR) for mortality 26% higher. The interpretation is that progressive failure of SVG leads to adverse cardiac events, which lead to an excess of death in this arm. Cox = Cox proportional hazards; KM = Kaplan-Meier.

artery disease), age and dialysis status at time of surgery, severe limitation due to heart condition (angina Canadian Cardiovascular Score III/IV and New York Heart Association functional class III/IV), and

history of heart and vascular disease (myocardial infarction, and cerebrovascular and peripheral vascular disease). Other pre-operative conditions also considered were emergency surgery, isolated CABG,

FIGURE 1 Y Graft Construction



(A) Radial artery sutured to left internal mammary artery while placed over the thymus before cannulation for cardiopulmonary bypass. (B) Y graft positioned at the border of the heart, where the conduit passes the pericardium at the level of the left atrial appendage. Left internal mammary artery used to revascularize the left anterior descending artery territory, and radial artery used to revascularize circumflex and right coronary artery territories.

redo CABG, arrhythmias, heart valve disease, lung disease, and extent of coronary artery disease (left main, LAD, circumflex, and right coronary artery of >50% stenosis). The variable LIMA-LAD was enforced to reflect clinical practice of LIMA-LAD and supplementary SVG and to improve matching.

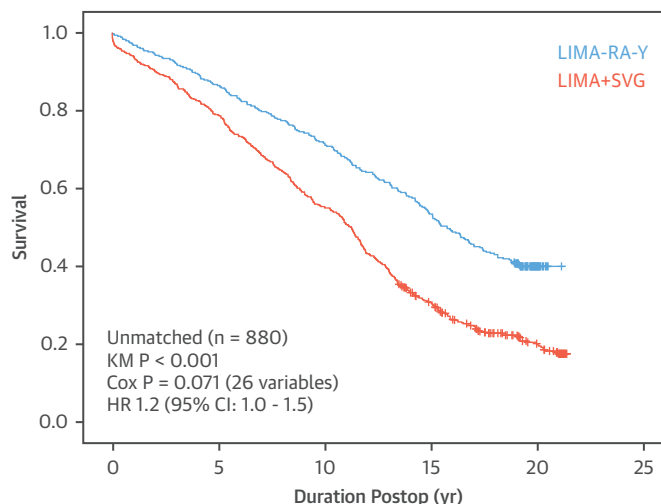
Missing data were infrequent in the unmatched groups and are listed in the tables; they were considered to be missing completely at random with nonsignificant Little's Missing Completely at Random Test ($p > 0.05$). Analysis was then performed on cases with complete data, and no imputation was used. For both unmatched and matched analyses, a proportionality test was conducted with a p value < 0.05 (hazard ratios are proportional).

RESULTS

BEFORE PSM. For the LIMA-RA-Y group, overall survival at the censor date was 13.8 ± 6.3 years (range: 0 to 21 years) post-operation. Death occurred in this group at 9.9 ± 5.4 years, with 53.5% (185 of 346) still alive at 15 years. For the LIMA + SVG group, overall survival was 10.9 ± 6.4 years (range: 0 to 21 years) post-operation; 27.9% were still alive at 15 years.

AFTER PSM. Two groups of 232 well-matched patients were formed, and there were no significant differences remaining for either comparison of

FIGURE 2 Survival With LIMA-RA-Y Versus LIMA + SVG (Unmatched, $n = 880$)

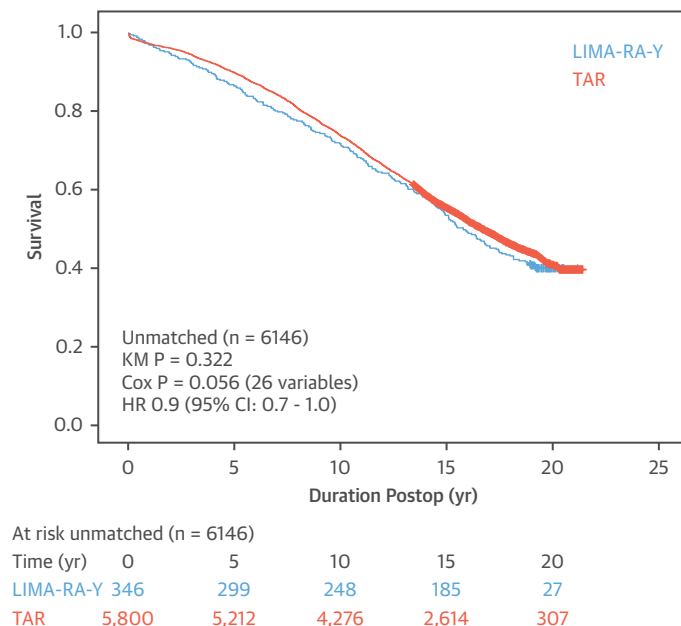


At risk unmatched ($n = 880$)

Time (yr)	0	5	10	15	20
LIMA-RA-Y	346	299	248	185	27
LIMA+SVG	534	421	295	149	62

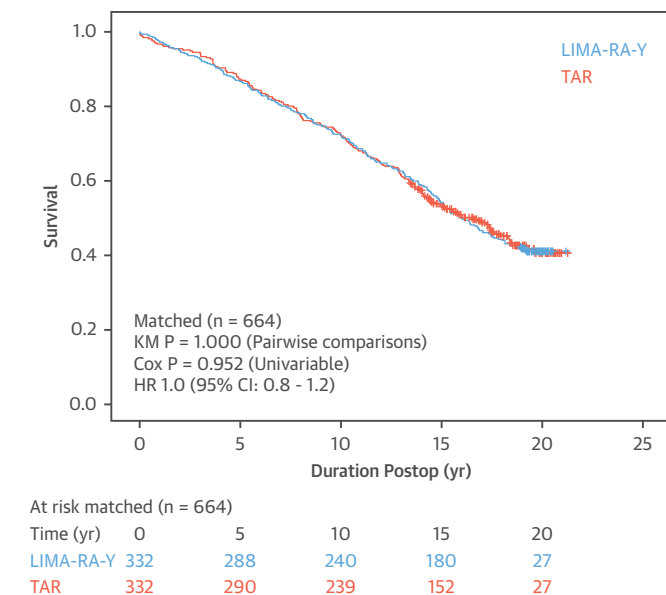
Unmatched survival up to 21 years' post-operation shows significantly lower survival for left internal mammary artery to left anterior descending artery and supplementary saphenous vein graft (LIMA + SVG) operation compared with the LIMA, radial artery, Y graft (LIMA-RA-Y) operation. The hazard ratio (HR) for mortality was 20% higher. CI = confidence interval; Cox = Cox proportional hazards; KM = Kaplan-Meier.

FIGURE 3 Survival LIMA-RA-Y Versus TAR (Unmatched, n = 6,146)



Unmatched survival analysis found no difference between the LIMA-RA-Y graft operation and total arterial revascularization (TAR) by any reconstruction method. Other abbreviations as in [Figure 2](#).

FIGURE 4 Survival LIMA-RA-Y Versus TAR (Matched, n = 664)



Propensity score-matched analysis found no difference in survival between the LIMA-RA-Y operation and TAR by any reconstruction method, which indicates that the survival advantage of this technique is by way of achieving TAR. Abbreviations as in [Figure 2](#).

LIMA + SVG ([Table 1](#)). Similarly, for the analysis with other TAR configurations, there were 332 well-matched pairs ([Table 2](#)).

SURVIVAL. Survival of LIMA + SVG for unmatched groups was worse than for LIMA-RA-Y at up to 21 years (KM, $p < 0.001$) ([Figure 2](#)) and for PSM groups (KM, $p = 0.043$; Cox hazard ratio: 1.3; 95% confidence interval: 1.0 to 1.6; $p = 0.038$) ([Central Illustration](#)). Survival of the LIMA-RA-Y patients compared with other TAR patients found no significant difference in the unmatched ([Figure 3](#)) or the PSM groups ([Figure 4](#)).

DISCUSSION

The LIMA-RA-Y is a highly efficient technique for the achievement of TAR, allowing for simultaneous harvesting of just 2 conduits, which when joined together as a Y graft, can be used to reliably and flexibly revascularize all 3 coronary territories. To the best of our knowledge, the present study is the longest and most comprehensive follow-up of the LIMA-RA-Y technique to date.

A common view is that LIMA-LAD is the single largest, possibly the only, important graft in coronary surgery. We therefore sought to ensure that the comparison included LIMA-LAD as a graft in both groups so that any variation in survival reflected the remaining grafts performed. Our study found that LIMA + SVG had lower survival than the LIMA-RA-Y technique. An additional benefit of the Y-graft configuration is that only 2 arterial conduits can be used to achieve TAR even in triple coronary territory disease. We found no difference between the LIMA-RA-Y and other TAR reconstruction techniques, which suggests long-term equivalence between TAR strategies.

The magnitude of the survival hazard ratio for LIMA + SVG was ~30% lower in the late term after surgery. Although our data cannot attribute cause, this finding is consistent with our understanding of the progressive failure of SVG due to the development of conduit atheroma, particularly in the first 5 years after surgery ([10,14](#)). Myocardium that is dependent on conduit flow will incur ischemic consequences when the conduit fails. The findings would also be consistent with an absence of atheroma development in arterial conduits, including internal mammary and radial arterial conduits, with long-term patency in conduits surviving early graft failure due to competitive flow ([1,3](#)).

The lack of difference in long-term survival between the LIMA-RA-Y and other TAR reconstruction

TABLE 1 LIMA-RA-Y Versus LIMA + SVG Propensity Score Matched With 26 Variables

	Before Matching				After Matching			
	LIMA-RA-Y (n = 346)	LIMA + SVG (n = 534)	p Value	Std Diff (%)	LIMA-RA-Y (n = 232)	LIMA + SVG (n = 232)	p Value	Std Diff (%)
No. of grafts	3.4 ± 0.8	3.1 ± 0.9	<0.001	36.7	3.3 ± 0.8	3.3 ± 0.8	0.717	3.1
LIMA to LAD	342 (99)	492 (92)	<0.001	32.4	228 (98)	230 (99)	0.687	-7.6
Male	261 (75)	414 (78)	0.514	7.5	182 (78)	182 (78)	1.000	0.0
Age at surgery, yrs	64.8 ± 10.3	70.2 ± 9.5	<0.001	-53.8	67.0 ± 9.7	67.7 ± 9.8	0.329	-7.6
Age category								
≥80 yrs	15 (4)	60 (11)			11 (5)	13 (6)		
70-79 yrs	106 (31)	255 (48)			90 (39)	95 (41)		
60-69 yrs	120 (35)	145 (27)			83 (36)	77 (33)		
50-59 yrs	70 (20)	51 (10)			33 (14)	31 (13)		
<50 yrs	35 (10)	23 (4)			15 (6)	16 (7)		
Missing	0 (0)	0 (0)			0 (0)	0 (0)		
Current smoker	12 (3)	27 (5)	0.315	-8.5	12 (5)	9 (4)	0.648	6.2
Missing	0 (0)	12 (2)			0 (0)	0 (0)		
Family history of CAD	140 (40)	192 (36)	0.226	7.5	86 (37)	81 (35)	0.709	4.5
Missing	0 (0)	5 (1)			0 (0)	0 (0)		
Diabetes	46 (13)	99 (19)	0.041	-14.5	40 (17)	38 (16)	0.897	2.3
Missing	0 (0)	5 (1)			0 (0)	0 (0)		
Hypercholesterolemia	251 (73)	315 (59)	<0.001	23.4	153 (66)	163 (70)	0.382	-9.2
Missing	0 (0)	5 (1)			0 (0)	0 (0)		
Hypertension	212 (61)	338 (63)	0.432	-6.5	140 (60)	142 (61)	0.929	-1.8
Missing	0 (0)	5 (1)			0 (0)	0 (0)		
Obesity	88 (25)	106 (20)	0.096	12.5	51 (22)	57 (25)	0.590	-6.1
Missing	0 (0)	17 (3)			0 (0)	0 (0)		
Any valve disease	49 (14)	141 (26)	<0.001	-33.0	45 (19)	39 (17)	0.532	6.7
Missing	0 (0)	39 (7)			0 (0)	0 (0)		
Myocardial infarction	172 (50)	267 (50)	0.836	-3.8	116 (50)	119 (51)	0.852	-2.6
Missing	0 (0)	6 (1)			0 (0)	0 (0)		
Cerebrovascular disease	11 (3)	48 (9)	0.001	-24.5	10 (4)	12 (5)	0.832	-4.0
Missing	0 (0)	6 (1)			0 (0)	0 (0)		
Peripheral vascular disease	32 (9)	61 (11)	0.313	-7.7	27 (12)	25 (11)	0.880	2.7
Missing	0 (0)	6 (1)			0 (0)	0 (0)		
Dialysis	3 (1)	9 (2)	0.381	-8.1	3 (1)	3 (1)	1.000	0.0
Missing	0 (0)	14 (3)			0 (0)	0 (0)		
Left main disease (>50% stenosis)	56 (16)	123 (23)	0.008	-19.1	43 (19)	48 (21)	0.630	-5.4
Missing	0 (0)	14 (3)			0 (0)	0 (0)		
LAD >50% stenosis	335 (97)	494 (93)	0.231	9.2	227 (98)	224 (97)	>0.99	7.8
Circumflex >50% stenosis	304 (88)	447 (84)	0.474	6.7	202 (87)	201 (87)	>0.99	1.3
Right coronary >50% stenosis	306 (88)	432 (81)	0.032	14.0	200 (86)	204 (88)	0.687	-5.1
Severe angina (CCS III/IV)	202 (58)	306 (57)	0.944	-2.1	139 (60)	141 (61)	0.923	-1.8
Missing	0 (0)	6 (1)			0 (0)	0 (0)		
Severe activity limitation (NYHA functional class III/IV)	218 (63)	347 (65)	0.427	-9.2	151 (65)	150 (65)	>0.99	0.9
Missing	0 (0)	6 (1)			0 (0)	0 (0)		
Lung disease (COPD)	41 (12)	64 (12)	>0.99	-2.3	27 (12)	27 (12)	1.000	0.0
Missing	0 (0)	6 (1)			0 (0)	0 (0)		
Emergency surgery	7 (2)	35 (7)	0.002	-21.1	7 (3)	5 (2)	0.774	5.4
Missing	0 (0)	0 (0)			0 (0)	0 (0)		
Preoperative arrhythmia	129 (37)	119 (22)	<0.001	32.4	74 (32)	76 (33)	0.922	-1.8
Missing	0 (0)	6 (1)			0 (0)	0 (0)		
Isolated CABG	310 (90)	435 (81)	0.001	24.4	200 (86)	203 (88)	0.775	-3.8
Missing	0 (0)	0 (0)			0 (0)	0 (0)		
Primary CABG	335 (97)	514 (96)	0.712	2.3	226 (97)	228 (98)	0.754	-5.9
Missing	0 (0)	0 (0)			0 (0)	0 (0)		

Values are mean ± SD or n (%), unless otherwise indicated.

CABG = coronary artery bypass grafting; CAD = coronary artery disease; CCS = Canadian Cardiovascular Score; COPD = chronic obstructive pulmonary disease; LAD = left anterior descending artery; LIMA = left internal mammary artery; LIMA-RA-Y = left internal mammary artery, radial artery, Y graft; NYHA = New York Heart Association; Std Diff = standardized difference; SVG = saphenous vein graft.

	Before Matching				After Matching			
	LIMA-RA-Y (n = 346)	TAR (n = 5,800)	p Value	Std Diff (%)	LIMA-RA-Y (n = 332)	TAR (n = 332)	p Value	Std Diff (%)
No. of grafts	3.4 ± 0.8	2.8 ± 1.1	<0.001	60.2	3.4 ± 0.8	3.4 ± 0.9	0.884	1.1
LIMA to LAD	342 (99)	5,086 (88)	<0.001	45.7	328 (98.8)	331 (99.7)		-10.5
Male	261 (75)	4,315 (74)	0.704	-2.2	254 (76.5)	254 (76.5)	1.000	0.0
Age at surgery, yrs	64.8 ± 10.3	66.0 ± 10.4	0.033	-12.3	64.7 ± 10.3	65.6 ± 10.5	0.282	-8.4
Age category								
≥80 yrs	15 (4)	390 (7)			15 (4.5)	23 (6.9)		
70-79 yrs	106 (31)	1,905 (33)			101 (30.4)	102 (30.7)		
60-69 yrs	120 (35)	1,861 (32)			113 (34.0)	109 (32.8)		
50-59 yrs	70 (20)	1,220 (21)			69 (20.8)	71 (21.4)		
<50 yrs	35 (10)	424 (7)			34 (10.2)	27 (8.1)		
Missing	0 (0)	0 (0)			0 (0.0)	0 (0.0)		
Current smoker	12 (3)	316 (5)	0.111	-10.2	12 (3.6)	9 (2.7)	0.375	5.2
Missing	0 (0)	52 (1)			0 (0.0)	0 (0.0)		
Family history of CAD	140 (40)	2,595 (45)	0.106	-10.9	134 (40.4)	128 (38.6)	0.664	3.7
Missing	0 (0)	39 (1)			0 (0.0)	0 (0.0)		
Diabetes	46 (13)	935 (16)	0.174	-9.0	46 (13.9)	42 (12.7)	0.695	3.5
Missing	0 (0)	39 (1)			0 (0.0)	0 (0.0)		
Hypercholesterolemia	251 (73)	4,210 (73)	0.852	-4.0	241 (72.6)	229 (69.0)	0.331	7.9
Missing	0 (0)	39 (1)			0 (0.0)	0 (0.0)		
Hypertension	212 (61)	3,730 (64)	0.203	-9.6	205 (61.7)	202 (60.8)	0.869	1.9
Missing	0 (0)	39 (1)			0 (0.0)	0 (0.0)		
Obesity	88 (25)	1,603 (28)	0.295	-6.3	84 (25.3)	271 (81.6)	0.259	9.3
Missing	0 (0)	121 (2)			0 (0.0)	0 (0.0)		
Any valve disease	49 (14)	1,292 (22)	<0.001	-22.5	47 (14.2)	50 (15.1)	0.824	-2.6
Missing	0 (0)	39 (1)			0 (0.0)	0 (0.0)		
Myocardial infarction	172 (50)	2,330 (40)	0.001	17.1	164 (49.4)	168 (50.6)	0.817	-2.4
Missing	0 (0)	43 (1)			0 (0.0)	0 (0.0)		
Cerebrovascular disease	11 (3)	343 (6)	0.032	-13.7	11 (3.3)	12 (3.6)	>0.99	-1.6
Missing	0 (0)	43 (1)			0 (0.0)	0 (0.0)		
Peripheral vascular disease	32 (9)	299 (5)	0.003	15.5	27 (8.1)	34 (10.2)	0.427	-7.3
Missing	0 (0)	43 (1)			0 (0.0)	0 (0.0)		
Dialysis	3 (1)	23 (0)	0.180	5.7	3 (0.9)	3 (0.9)	>0.99	0.0
Missing	0 (0)	51 (1)			0 (0.0)	0 (0.0)		
Left main disease (>50% stenosis)	56 (16)	918 (16)	>0.99	-0.1	54 (16.3)	53 (16.0)	>0.99	0.8
Missing	0 (0)	133 (2)			0 (0.0)	0 (0.0)		
LAD >50% stenosis	335 (97)	5,262 (91)	0.003	17.8	321 (96.7)	328 (98.8)	0.118	-14.2
Circumflex >50% stenosis	304 (88)	4,275 (74)	<0.001	32.3	291 (89.7)	290 (87.3)	>0.99	0.9
Right coronary >50% stenosis	306 (88)	4,059 (70)	<0.001	42.9	292 (88.0)	288 (86.7)	0.689	3.6
Severe angina (CCS III/IV)	202 (58)	2,854 (49)	0.002	16.1	189 (56.9)	182 (54.8)	0.639	4.2
Missing	0 (0)	43 (1)			0 (0.0)	0 (0.0)		
Severe activity limitation (NYHA functional class III/IV)	218 (63)	3,248 (56)	0.016	11.7	204 (61.4)	205 (61.7)	>0.99	-0.6
Missing	0 (0)	43 (1)			0 (0.0)	0 (0.0)		
Lung disease (COPD)	41 (12)	454 (8)	0.011	12.7	36 (10.8)	37 (11.1)	>0.99	-1.0
Missing	0 (0)	43 (1)			0 (0.0)	0 (0.0)		
Emergency surgery	7 (2)	98 (2)	0.666	2.3	6 (1.8)	6 (1.8)	>0.99	2.4
Missing	0 (0)	19 (0)			0 (0.0)	0 (0.0)		
Pre-operative arrhythmia	129 (37)	648 (11)	<0.001	63.2	115 (34.6)	115 (34.6)	>0.99	0.0
Missing	0 (0)	38 (1)			0 (0.0)	0 (0.0)		
Isolated CABG	310 (90)	4,935 (85)	0.023	13.8	297 (89.5)	299 (90.1)	0.899	-2.0
Missing	0 (0)	0 (0)			0 (0.0)	0 (0.0)		
Primary CABG	335 (97)	5,545 (96)	0.341	6.2	321 (96.7)	322 (97.0)	>0.99	-1.7
Missing	0 (0)	0 (0)			0 (0.0)	0 (0.0)		

Values are mean ± SD or n (%), unless otherwise indicated.

TAR = total arterial revascularization (no use of SVG and excludes the LIMA-RA-Y patients); other abbreviations as in [Table 1](#).

techniques implies that the likely benefit of the LIMA-RA-Y technique is in providing an alternative strategy to allow SVG avoidance. Furthermore, it provides confidence that the use of a single inflow pedicled arterial graft does not reduce survival compared with other TAR reconstruction strategies. Another potential benefit of the LIMA-RA-Y or use of bilateral RA is a reduction in the need for bilateral internal mammary artery harvest, which may reduce lower deep sternal wound infections (15–17), although this topic was not examined in this analysis.

Although all-cause mortality was used as the primary endpoint in the current study, it was assumed in this analysis that noncardiac mortality would be similar in all comparison groups and that excess mortality reflected cardiac mortality. Major adverse cardiac and cerebral events were not considered in this analysis.

The distribution of coronary stenoses >50% was similar in all groups, including for the RCA territory; triple vessel disease was present in most patients (Tables 1 and 2). Following PSM, RCA stenosis >50% was present in 86% in the LIMA-RA-Y group and in 88% in the LIMA + SVG group ($p = 0.687$). In the LIMA-RA-Y group, all RCAs were grafted with composite RAs; for the LIMA + SVG group, all RCAs were grafted with SVG.

STUDY LIMITATIONS. These data are retrospective and limited to all-cause mortality. The Australian Death Register cause of death relies on the diagnosis of the practitioner completing the death certificate, and this process is considered to be potentially inaccurate. Our data are contemporaneous in time, from the same group of surgeons and from a single institution, and we attempted to mitigate selection bias by using a severe PSM with a very small caliper (0.05) and the use of a large number of variables ($n = 26$) to closely match patients. At the time of this study, reconstruction techniques were evolving, from SVG being used in most patients to exclusive arterial conduit use in most. Individual conduit selection was per surgeon preference rather than according to an institutional or conventional norm or policy, and it is

unlikely that any important variables for conduit selection were not captured in this PSM analysis. Nevertheless, some differences in groups may exist despite matching. From our initial publication (11), we know that early death was only 0.2% at 30 days, which may be indicative of a low incidence of early graft failure. However, by examining survival into the “late” period (>10 years’ post-operation), we would further mitigate influence of early graft failure on survival.

CONCLUSIONS

Use of LIMA + SVG has worse survival than LIMA-RA-Y in achieving total arterial revascularization. There was no difference between Y graft and other TAR configurations.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL

SKILLS: Aortocoronary saphenous vein bypass grafts (SVG) are prone to failure due to development of accelerated atherosclerosis, while arterial conduits may fail early in the post-operative period due to competitive flow, but there is scant evidence of later failure. Total (triple coronary territory) revascularization achieved with exclusively arterial grafts by joining left radial artery and LIMA conduits together (Y-graft) is associated with improved patient survival up to 21 years post-operatively compared with combinations of LIMA and SVG.

TRANSLATIONAL OUTLOOK: Prospective studies are needed to determine which patients gain the greatest advantage from total arterial coronary revascularization, define the optimum composite arterial graft configurations, and identify situations in which hybrid procedures involving arterial grafts and catheter-based coronary revascularization may be advantageous.

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