Does a third arterial conduit to the right coronary circulation improve survival?

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ABSTRACT

Background: The long-term benefits of a third arterial conduit to the right circulation in triple-vessel disease remain debatable. This retrospective, single-center, propensity-matched study investigates the impact of a third arterial conduit to the right circulation on early and intermediate survival after coronary artery bypass grafting.

Methods: Data were retrospectively collected from 2004 to 2014 for all surgical revascularizations for triple-vessel disease with at least 2 arterial conduits to the left circulation and a third arterial or venous conduit to the right circulation. A total of 167 pairs were propensity matched to arterial versus venous third conduit to right circulation. Hazard functions were obtained with Cox multivariate regression and Kaplan-Meier survival curves were compared between the matched cohorts.

Results: Extracardiac arteriopathy, logistic euroSCORE, and left main stem disease were significant predictors of adverse survival. A third arterial conduit to the right circulation was not a significant predictor of improved survival in multivariate analysis (HR, 0.72; 95% CI, 0.34-1.55; $P = .411$). 30-day mortality was 0.6% in both groups. There was no significant difference in early or intermediate survival in the propensity-matched groups (venous vs arterial, 99.2% vs 99.2%; $P = 1.000$ at 1 year; 85.2% vs 88.8%; $P = .248$ at 5 years and 69.2% vs 88.8%; $P = .297$ at 7 years)

Conclusions: The use of a third arterial versus a venous conduit to the right circulation does not improve early or intermediate survival up to 7 years in triple-vessel coronary artery disease in this study. Longer follow-up and larger cohorts may be needed for differences to emerge. (J Thorac Cardiovasc Surg 2018;155:855-60)

Overall survival by addition of a third arterial or venous conduit to the right coronary circulation.

Central Message

The use of a third arterial versus a venous conduit to the right circulation does not improve early or intermediate survival up to 7 years in triple-vessel coronary artery disease.

Perspective

The use of an arterial conduit has traditionally been associated with better patency rates and better clinical outcomes during revascularization of left coronary territories; however, the clinical usefulness to the right circulation remains debatable. In this study, we compare early and intermediate survival by the type of conduit to the right circulation during triple-vessel disease revascularization.

See Editorial Commentaries pages 861 and 863.

See Editorial page 853.

Arterial conduits have better patency rates and have been associated with a survival benefit in surgical revascularization. The choice of additional conduit to the right coronary circulation has been a radial artery (RA), right internal

thoracic artery (ITA) or rarely a right gastroepiploic artery. Patency rates for right-sided grafts have generally been lower than those for left-sided grafts both for arterial and for venous grafts.^{1,2} There has been a call for additional arterial grafts to improve survival.^{3,4} Additional arterial grafting has not been shown to provide survival benefits from revascularization of the right coronary territory.

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Abbreviations and Acronyms

CABG	=	Coronary artery bypass grafting
CI	=	Confidence interval
HR	=	Hazard ratio
ITA	=	Internal thoracic artery
LAD	=	Left anterior descending artery
LVEF	=	Left ventricular ejection fraction
MI	=	Myocardial infarction
RA	=	Radial artery
RIMA	=	Right internal mammary artery
SVG	=	Saphenous vein graft

The aim of this study was to assess the early and intermediate survival benefit of a third arterial graft to the right coronary circulation as opposed to venous grafts.

METHODS

Data for isolated coronary artery bypass grafting (CABG) were retrospectively collected from 2004 to 2014 from the New Cross Hospital database (PATS [Dentrite Clinical Systems Ltd, Henley-on-Thames, United Kingdom]). We included all patients with triple-vessel disease with arterial grafts to left anterior descending artery (LAD) and circumflex circulation and a third venous or arterial graft (ITA or RA) to the right coronary circulation (right coronary artery or posterior descending or posterior ventricular artery) (Figure 1). Patients with a venous graft to the circumflex system, single-vessel/double-vessel disease and those with other concomitant procedures were excluded. The use of radial arteries to the right or left circulation was restricted to vessels with severe lesions. The hospital database is reviewed, audited, and validated monthly by audit officers and linked to a national UK database. Consent for individual use of data was waived because of the nature of the study and previous approval for use of such data at the time of operative consent. Long-term survival statistics were collected from the NICOR (National Institute of Cardiac Outcomes Research, United Kingdom) database (release June 2015).

Data Analysis

Baseline demographic characteristics for CABG were stratified for arterial versus venous third conduit to the right coronary circulation after at least 2 other arterial grafts to the left circulation. Distributions from each variable were visually inspected and normality was tested by a Shapiro-Wilcoxon W test. Continuous variables were compared using a Mann-Whitney test and categorical variables by χ^2 test. $P \leq .05$ was considered significant.

Propensity Score Matching

Propensity matching was used to balance the covariates in the nonrandomized, observational data. The following covariates were included in the propensity match: age, logistic euroSCORE (European System for Cardiac Operative Risk Evaluation), body mass index, gender, hypercholesterolemia, pulmonary disease, neurologic disease, renal disease, hypertension, left main stem disease, diabetes, left ventricular ejection fraction (LVEF), New York Heart Association classification, previous percutaneous coronary intervention, and previous myocardial infarction. The definitions used for these risk factors were as previously described for calculation of euroSCORE by Roques et al.^{5,6}

The propensity score for use of a third arterial conduit to the right coronary circulation was estimated by logistic regression. Variables included in the propensity match model were chosen by clinical relevance

FIGURE 1. Data flowchart for patients included in the study. CABG, Coronary artery bypass grafting; ONS, Office for National Statistics; Cx, circumflex; LAD, left anterior descending artery; RCA, right coronary artery.

and included in the model by an iterative process until almost all variables were successfully balanced. The treated observations were posteriorly matched in a 1:1 ratio using the nearest-neighbor method with a caliper width of 0.2 of the standard deviation of the propensity score logit. Means, standard deviations, and proportions of baseline demographic characteristics were compared to ensure appropriate balance among groups and statistical significance was tested by comparing standardized bias among each of the variables; those with a standardized bias within $\pm 10\%$ were considered appropriately balanced (Figure 2). Despite sequential modeling, extracardiac arteriopathy and LVEF $<30\%$ remained unbalanced so these variables were incorporated in the multivariable analysis as described in the next section.

Hazard Functions and Survival Analysis

Kaplan-Meier survival curves were plotted for the matched and unmatched data and the equality of survivor functions was tested using a log-rank test. To analyze the association between risk factors and survival among the propensity-matched cohorts, each covariate was tested for prediction using a Cox proportional hazards model or a log-rank test, respectively. All covariates with a $P \leq .2$ as well as those unbalanced were included in the multivariate model, and the proportional hazard assumption was tested using Schoenfeld residuals. Hazard ratios (HRs) were calculated for each variable. Overall survival was compared using a log-rank test; this test was stratified by the pair identification in the propensity-matched cohort.

RESULTS

A total of 598 patients with triple-vessel disease were included in the study (274 venous; 324 arterial). All patients had an ITA to the LAD and at least 1 arterial graft (RA or ITA) to the circumflex circulation. Median follow-up was 85 (interquartile range, 68-105) months versus 51 (interquartile range, 35.5-87) months ($P = .024$) for venous and arterial grafts, respectively. The baseline demographics and operative characteristics are shown in Table 1.

FIGURE 2. Percent bias plot from the propensity-matching model. NYHA, New York Heart Association; BMI, body mass index; MI, myocardial infarction; PCI, percutaneous coronary intervention; LVEF, left ventricular ejection fraction; LM, left main.

A total of 167 pairs were propensity matched to the venous or arterial (third conduit) to right coronary circulation. Most of the arterial grafts to the right circulation were RAs (Tables E1 and E2). Of those patients who had bilateral internal mammary arteries to the left circulation, 60 had single radial conduits to the right circulation. Cox proportional hazards regression analysis in the propensity-matched cohorts identified extracardiac arteriopathy, logistic euroSCORE, and left main stem disease as significant predictors of adverse survival (Table 2). A third arterial graft to the right coronary circulation as opposed to a venous conduit was not a significant predictor of improved early or late survival (univariable: HR, 0.65; 95% confidence interval [CI], 0.31-1.35; $P = .246$) (multivariable: HR, 0.72; 95% CI, 0.34-1.55; $P = .411$).

Early and Midterm Survival (up to 5 Years)

The 30-day mortality was comparable in the 2 groups: unmatched, 99.6% (venous) versus 98.8% (arterial), $P = .225$ and 99.2% ($P = 1.000$) for both propensity-matched groups. The survival did not differ significantly in the unmatched and propensity-matched groups at 1, 2, 3, and 5 years (Figure 3 and Table E3).

Intermediate Survival (up to 7 Years)

There was no significant difference in survival in unmatched (69.01% vs 83.48%; $P = .84$) or matched cohorts (69.2% vs 88.8%; $P = .297$) at 7 years.

There was an accelerated decline in survival in the venous group both for unmatched and propensity-matched cohorts after 84 months. The differences in survival remained statistically insignificant up to 8 years. However, the numbers at risk were sufficiently low.

Right Internal Mammary Artery Versus RAs

Right internal mammary artery (RIMA) was used in 8.3% of the arterial grafts to the right circulation. There was no difference in survival between RIMA and RAs for the right circulation (overall log-rank, $P = .859$), although the numbers were small.

DISCUSSION

The benefits of total arterial revascularization especially for arterial grafts to the right coronary circulation remain debatable. There is a consensus that left internal mammary artery to LAD artery offers a long-term survival benefit and addition of another arterial graft to the left circulation improves survival.⁷⁻⁹ This evidence in recent studies has extended to the use of RAs as second-best conduits after ITAs.

Grau et al. recently failed to show any statistical difference in survival up to 14 years in comparison of RA and saphenous vein grafts (SVG) to right coronary circulation with bilateral ITA to the left circulation.¹⁰ At least 2 other recent propensity-matched studies have found similar results with the use of radial arteries as the third arterial conduit to right coronary circulation.¹¹

A common strategy for proponents of arterial revascularization is to use the 2 ITAs for the left circulation and an RA for the right coronary circulation. The use of the RA and ITA to the right coronary circulation is limited to good caliber vessels in right dominant systems and significant stenosis >80%. In situ right ITA conduit may be limited by its length for grafting beyond the crux. These constraints with length can be overcome with skeletonization and use as a free graft with proximal aortic anastomosis or as a Y-graft from any of the left-sided grafts. The radial arteries have superb handling and length. These are easier to use as free or Y-grafts, with or without proximal anastomosis on the ascending aorta. For moderate right-sided lesions, the conventional wisdom has been to prefer venous conduits. This preference is because of stringing commonly seen in arterial conduits as a result of native competitive flow in moderate severity lesions.

It is reasonable to assume that the benefits of a third arterial graft may be caused by superior graft patency. Reported arterial graft patencies have been superior to SVGs both for right-sided and left-sided coronary circulations in randomized trials with protocol angiograms.^{12,13} However, observational studies have reported better SVG patencies in early and midterm results compared with arterial grafts.¹⁴⁻¹⁶ In a review

TABLE 1. Demographic characteristics

	Venous (n = 274) Median (IQR)	Arterial (n = 324) Median (IQR)	P value	Venous (n = 132) Median (IQR)	Arterial (n = 132) Median (IQR)	P value
Age (y)	67 (59-73)	67 (59-73)	.994	67 (60-72)	65 (58-73.5)	.902
Crossclamp time (min)	51.5 (42-64)	37 (25-59)	<.001	84 (69-106)	47 (14-85)	<.001
Follow-up (mo)	85 (68-105)	51 (35.5-87)	.024	83.4 (56.6-89.7)	79 (70.9-89.4)	<.001
Bypass time (min)	58.3 (40.6-86.9)	71.7 (50-83.5)	<.001	50 (42-63)	35 (0-57)	<.001
EuroSCORE	2 (1-4)	3 (2-5)	.001	2 (1-4)	2 (1-3.5)	.235
Logistic EuroSCORE	1.6 (0.94-3.2)	2.2 (1.4-3.7)	.003	1.69 (1.07-2.98)	1.66 (1.11-2.54)	.376
BMI	28.5 (25.8-31.3)	28.4 (25.7-30.7)	.632	28.87 (2.7-31.5)	28.68 (26.4-31.6)	.626
	n (%)	n (%)				
Gender						
Female	54 (19.71)	43 (13.27)	.033	26 (19.70)	22 (16.67)	.608
Male	220 (80.29)	281 (86.73)		106 (80.30)	110 (83.33)	
Sinus rhythm	66 (24.09)	93 (28.70)	.203	98 (74.24)	101 (76.52)	.784
Operative urgency						
Elective	179 (65.33)	221 (68.21)	.456	106 (80.30)	114 (86.36)	.229
Nonelective	95 (34.67)	103 (31.79)		26 (19.70)	18 (13.64)	
Extent of coronary vessel disease						
3-vessel	274 (100.00)	324 (100.00)	1.000	132 (100.00)	132 (100.00)	1.000
Left main disease	84 (30.66)	69 (21.30)	.009	40 (30.30)	40 (30.30)	1.000
Pulmonary disease	35 (12.77)	38 (11.73)	.697	20 (15.15)	21 (15.91)	1.000
Neurologic disease	23 (8.39)	33 (10.19)	.462	7 (5.30)	6 (4.55)	1.000
Renal disease	66 (24.09)	51 (15.74)	.010	0 (0.00)	0 (0.00)	1.000
Hypertension	194 (70.80)	227 (70.06)	.843	89 (67.42)	90 (68.18)	1.000
Diabetes	69 (25.18)	88 (27.16)	.584	29 (21.97)	31 (23.48)	1.000
LVEF <30%	15 (5.47)	8 (2.47)	.057	8 (6.06)	5 (3.79)	.549
CCS class of angina						
I-II	129 (47.08)	135 (41.67)	.184	89 (67.42)	90 (68.18)	1.000
III-IV	145 (52.92)	189 (58.33)		43 (32.58)	42 (31.82)	
NYHA status						
I-II	137 (50.00)	150 (46.30)	.366	74 (56.06)	73 (55.30)	1.000
III-IV	137 (50.00)	174 (53.70)		58 (43.94)	59 (44.70)	
Previous PCI	45 (16.42)	41 (12.65)	.191	18 (13.64)	18 (13.64)	1.000
Extracardiac arteriopathy	59 (21.53)	45 (13.89)	.014	34 (25.76)	20 (15.15)	.016
Previous MI	154 (56.20)	173 (53.40)	.492	79 (59.85)	80 (60.61)	1.000

IQR, Interquartile range; BMI, body mass index; LVEF, left ventricular ejection fraction; CCS, Canadian Cardiovascular Society; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; MI, myocardial infarction.

comparing SVG with right ITA, Mukherjee et al.¹⁷ found that SVGs had superior graft functionality (odds ratio, 6.1; 95% CI, 2.4-15) compared with the other conduits. Graft function was negatively influenced by the minimum lumen diameter (odds ratio, 0.11; CI, 0.05-0.25). In the RAPCO (Radial Artery Patency and Clinical Outcomes) study, patency of free arterial conduits and SVG was 89.1% versus 82.4%, respectively, which did not differ significantly ($P = .09$) at 5 years.¹⁸ The trial failed to show any significant differences in angiographic or clinical

outcomes between arterial and venous grafts even at 8 years.

The physiology of the right coronary circulation is also probably different from the left. It has a smaller runoff even in right dominant circulations. The size of the distal vessels is likely to be smaller than on the left. It predominantly supplies a low-pressure chamber of the heart with lesser muscle mass compared with the left. Late graft failure may therefore be more forgiving for the right circulation compared with the left. Likewise, the benefits of

TABLE 2. Univariate and multivariate Cox regression analysis

	Univariable			Multivariable		
	HR	95% Confidence interval	P value	HR	95% Confidence Interval	P value
Artery to right circulation	0.65	0.31-1.35	.246	0.72	0.34-1.55	.411
Age	1.02	0.98-1.06	.383			
Logistic euroSCORE	1.23	1.14-1.33	<.001	1.24	1.10-1.39	<.001
BMI	1.01	0.93-1.10	.734			
Extracardiac arteriopathy	3.97	1.92-8.23	<.001	1.95	0.92-4.14	.083
Female gender	2.10	0.96-4.61	.064	2.09	0.95-4.56	.066
Pulmonary disease	0.61	0.18-2.02	.418			
Neurologic disease	0.71	0.10-5.24	.74			
Hypertension	0.64	0.30-1.33	.23			
LM disease	0.95	0.43-2.09	.902			
Diabetes	0.69	0.26-1.81	.45			
LVEF <30%	2.27	0.69-7.50	.179	0.26	0.05-1.39	.115
NYHA III-IV	0.92	0.44-1.92	.821			
Previous PCI	1.56	0.63-3.82	.334			
Previous MI	1.22	0.57-2.62	.614			
Date of operation	0.99	0.99-1.00	.109	1.00	0.99-1.00	.234

HR, Hazard ratio; BMI, body mass index; LM, left main; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; MI, myocardial infarction.

superior patency might not affect clinical outcomes or long-term survival.

There are likely explanations why our study might have failed to show any benefit from an additional arterial graft to the right coronary circulation. The mean age in both groups in this study was around 66 years. The survival benefits of multiple arterial grafting may not be fully realized before 10-15 years. Studies that have shown survival benefits with multiple arterial grafting had long follow-ups.¹⁹⁻²² The recent results of the Arterial

Revascularization Trial have similarly failed to show benefit even from a second ITA at 5 years. Our follow-up of 10 years may not have been long enough to realize these differences. The survival curves for the venous group digress sharply downward after 7 years in our study. This digression may be caused by late vein graft loss and is likely to have been significant with a longer follow-up if numbers at risk remain significant.

Although propensity matched, this is a retrospective analysis, which could not have corrected for all the inherent

FIGURE 3. Overall survival in unmatched (A) and propensity-matched groups (B) stratified by the type of conduit to the right coronary circulation. CI, Confidence interval.

biases in patient selection. Propensity matching could be achieved only for 44% of the patients (264/598). This factor suggests a significant heterogeneity between groups. Small subgroup numbers and limitations of data did not allow further analysis for confounders such as surgical techniques, surgeons, and arterial grafting trends over the decade of the study.

The lesion severity for the right-sided grafts is an important correlate for graft patency, especially RAs. Angiographic graft patency was also not assessed in this study for its correlation to survival.

Age cutoff for any benefit from arterial grafts for the left circulation has been 65-70 years and even lower for those with diabetes.^{23,24} For multiple arterial grafting including to the right circulation, age remains controversial. The mean age in this study was 66 years and might have affected the benefits of multiple arterial grafting.

Data for secondary prevention and control of risk factors and compliance with medical therapy were not available. Low compliance could have significant bearing on graft patency rates.

CONCLUSIONS

A third arterial graft to the right coronary circulation does not improve early or intermediate survival for up to 7 years in this study. Longer follow-up and larger cohorts may be needed to show any benefits.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: coronary, bypass, arterial conduits, right circulation

TABLE E1. Territory and distribution of grafts to right coronary circulation

	Venous (n = 274) Mean ± SD	Arterial (n = 324) Mean ± SD	P value
Total conduits	3.99 ± 0.83	3.44 ± 0.61	<.001
n (%)		n (%)	
RCA			
LIMA	0 (0.0)	1 (0.31)	<.001
RIMA	0 (0.0)	10 (3.09)	
Radial	0 (0.0)	29 (8.95)	
SVG	10 (3.6)	0 (0.00)	
RCA-LV			
LIMA	0 (0.0)	0 (0.00)	<.001
RIMA	0 (0.0)	6 (1.85)	
Radial	0 (0.0)	51 (15.74)	
SVG	26 (9.5)	0 (0.00)	
RCA-PDA			
LIMA	0 (0.0)	0 (0.00)	<.001
RIMA	0 (0.0)	11 (3.40)	
Radial	0 (0.0)	219 (67.59)	
SVG	274 (100.0)	4 (1.23)	

SD, Standard deviation; RCA, right coronary artery; LIMA, left internal mammary artery; RIMA, right internal mammary artery; SVG, saphenous vein graft; RCA-LV, right coronary artery to the left ventricle; RCA-PDA, right coronary artery posterior descending.

TABLE E2. Territory and distribution of grafts to left coronary circulation

	Venous (n = 274) Mean ± SD n (%)	Arterial (n = 324) Mean ± SD n (%)	P value
LAD			
LIMA	261 (95.3)	316 (97.53)	<.001
RIMA	12 (4.4)	8 (2.47)	
Radial	1 (0.4)	0 (0.00)	
SVG	0 (0.0)	0 (0.00)	
OM1			
LIMA	11 (4.0)	6 (1.85)	<.001
RIMA	34 (12.4)	45 (13.89)	
Radial	174 (63.5)	227 (70.06)	
SVG	5 (1.8)	2 (0.62)	
OM2			
LIMA	1 (0.4)	2 (0.62)	<.001
RIMA	18 (6.6)	10 (3.09)	
Radial	67 (24.5)	55 (16.98)	
SVG	6 (2.2)	4 (1.23)	
LCx			
LIMA	1 (0.4)	1 (0.31)	<.001
RIMA	2 (0.7)	3 (0.93)	
Radial	8 (2.9)	3 (0.93)	
SVG	14 (5.1)	1 (0.31)	

SD, Standard deviation; LAD, left coronary artery; LIMA, left internal mammary artery; RIMA, right internal mammary artery; SVG, saphenous vein graft; OM, obtuse marginal; LCx, left circumflex.

TABLE E3. Survival in unmatched and propensity-matched cohorts

	%	Deaths	Number at risk	%	Deaths	Number at risk	<i>P</i> value
Unmatched							
	Venous (n = 274)			Arterial (n = 324)			
30-d	99.64	1	274	98.77	4	324	.225
1-y	95.93	5	268	96.28	4	316	.814
2-y	94.71	3	247	94.31	6	302	.847
3-y	89.46	10	221	91.31	8	280	.845
5-y	86	4	130	85.77	9	214	.587
7-y	69.01	8	73	83.48	1	74	.836
Propensity-matched							
	Venous (n = 132)			Arterial (n = 132)			
30-d	99.24	1	132	99.24	1	132	1.000
1-y	93.94	0	127	96.97	0	129	.706
2-y	92.41	2	124	96.97	1	128	.527
3-y	88.87	31	120	94.56	13	127	.248
5-y	85.22	24	85	88.75	59	111	.345
7-y	69.24	52	58	88.75	47	57	.297