Ann Thorac Cardiovasc Surg 2024: 30; 24-00029 doi: 10.5761/atcs.oa.24-00029

Original Article

Long-Term Outcomes of Coronary Artery Bypass Grafting Using an Internal Thoracic Artery versus a Radial Artery as a Second Arterial Graft

Ryoma Oda,[1] Kan Kajimoto,[2] Taira Yamamoto,[3] Daisuke Endo,[1] Takeshi Kinoshita,[1] Atsushi Amano,[1] and Minoru Tabata[1]

Purpose: To compare the outcomes of left circumflex artery (LCx) revascularization using an internal thoracic artery (ITA) or radial artery (RA) as the second arterial graft.
Methods: Patients who underwent primary isolated coronary artery bypass grafting with left anterior descending artery revascularization using an ITA and LCx revascularization using another bilateral ITA (BITA group) or an RA (ITA-RA group) were included. All-cause mortality (primary endpoint), cardiac death, major adverse cardiac events, in-hospital death, and deep sternal wound infection (secondary endpoints) were evaluated.
Results: Among 790 patients (BITA, n = 548 (69%); ITA-RA, n = 242 (31%)), no significant difference in all-cause mortality between the groups was observed (hazard ratio (HR): 0.87; 95% confidence interval (CI): 0.67–1.12; p = 0.27) during follow-up (mean, 10 years). Multivariate analysis revealed that the BITA group exhibited significantly lower rates of long-term all-cause mortality (HR: 0.63; 95% CI: 0.48–0.84; p = 0.01). In the propensity-matched cohort (n = 480, 240 pairs), significantly fewer all-cause deaths occurred in the BITA group (HR: 0.66; 95% CI 0.47–0.93; p = 0.02). There were no significant differences in secondary outcomes.
Conclusions: When used as second grafts for LCx revascularization, ITA grafts may surpass RA grafts in reducing all-cause mortality 10 years postoperatively.

Keywords: coronary artery bypass grafting, arterial graft, internal thoracic artery, revascularization of left circumflex artery, long-term outcome

[1]*Department of Cardiovascular Surgery, Juntendo University School of Medicine, Tokyo, Japan*
[2]*Department of Cardiovascular Surgery, Juntendo University School of Medicine Shizuoka Hospital, Izunokuni, Shizuoka, Japan*
[3]*Department of Cardiovascular Surgery, Juntendo University School of Medicine Nerima Hospital, Tokyo, Japan*

Received: February 6, 2024; Accepted: March 19, 2024
Corresponding author: Kan Kajimoto. Department of Cardiovascular Surgery, Juntendo University, 1129, Nagaoka, Izunokuni, Shizuoka 410-2295, Japan
Email: kajimoto@juntendo.ac.jp

Introduction

Surgical revascularization with an internal thoracic artery (ITA) graft for anastomosis to the left anterior descending (LAD) artery in coronary artery bypass grafting (CABG) is the reference standard owing to its superior long-term patency.[1,2] The optimal choice for a secondary graft, however, remains controversial. Although the 2021 American College of Cardiology/American Heart Association/Society for Cardiovascular Angiography and Intervention and the 2018 European Society of Cardiology/European Association for Cardio-Thoracic Surgery guidelines both recommend radial artery (RA) grafts over saphenous vein grafts (SVGs) and suggest bilateral ITA (BITA) grafting for specific patients,[3,4] there is still debate about whether the ITA or RA serves as a preferable second graft.[5–9] Recent research emphasizes a better long-term prognosis of arterial grafts than that of SVGs as secondary grafts.[10–12] In light of this, the Japan Circulation Society's 2018 guideline recommends the use of both the ITA and RA as class IIa secondary grafts. Notably, the guideline also endorses the use of the BITA for enhancing long-term cardiac outcomes and the in situ right ITA (RITA) graft anastomosis to LCx lesions, both as class Iia recommendations. However, the Japanese guidelines, largely based on Western research, may not fully align with the unique clinical presentation in the Japanese population. A notable study by Tsuneyoshi et al. is the only one that has evaluated the outcomes of CABG using the ITA or RA as a second arterial graft, specifically among Japanese patients.[13] Their findings, based on a 5-year follow-up, indicated comparable long-term outcomes between the RA anastomosed to the aorta and the RITA used as a secondary graft. However, to effectively evaluate the superiority of the second graft, longer-term follow-up is essential. We aimed to evaluate the 10-year outcomes post-CABG when either the ITA or RA is used as the secondary arterial graft among Japanese patients.

Materials and Methods

Ethics statement

All study protocols were approved by the Research Ethics Committee of the Faculty of Medicine at Juntendo University on April 21, 2022 (approval no. E22-0096-H01). The need for informed consent was waived owing to the retrospective nature of this study. This study was performed in accordance with the principles of the Declaration of Helsinki.

Patient selection and study design

This was a single-center, retrospective, observational study. Patients who underwent primary isolated CABG between July 2002 and December 2012 at the Juntendo University Hospital were included in this study. Among them, patients who met the following inclusion criteria were further selected: (i) the ITA [right ITA (RITA) or left ITA (LITA)] was used for LAD revascularization and (ii) left circumflex artery (LCx) revascularization was conducted using an ITA [bilateral ITA (BITA) group] or RA (ITA-RA group).

All data were extracted from the institutional database in which data were prospectively collected following the definitions of the Society of Thoracic Surgeons National Adult Cardiac Database (https://www.sts.org/registries/sts-national-database/adult-cardiac-surgery-database).

Operative procedure

Under general anesthesia, all patients underwent a median sternotomy in the frog-leg position. Almost all patients underwent off-pump CABG, performed according to internationally established techniques. All arterial grafts, including the ITA and RA, were harvested using a skeletonized technique with an ultrasound coagulation incision device (HARMONIC; ETHICON, Johnson & Johnson, New Brunswick, NJ, USA). The basic strategy for graft selection in CABG was to perform the LITA-LAD anastomosis first. The decision to use either the RA or RITA as the secondary graft depended on the surgeon's preference. The RA graft was avoided in patients with diabetes mellitus (DM) and chronic kidney disease (CKD, Stage 4 or 5) owing to the potential future need for a forearm arteriovenous fistula. An aortic no-touch strategy was selected when the ascending aorta exhibited plaque or calcification, which was assumed to indicate a high risk of stroke.

The following methods were employed to prevent deep sternal wound infection (DSWI): (i) ITA harvesting using the skeletonized technique, (ii) placement of a subcutaneous drain, (iii) avoidance of bone wax, (iv) adequate saline flushing before chest closure, and (v) administration of prophylactic antibiotics until after the postoperative 48 hours. Patients routinely began taking aspirin, statins, and β-blockers on the first day after surgery and continued unless contraindicated. For cases in which RA grafts were used, oral diltiazem was administered for 3 months postoperatively to prevent spasms in the RA graft.

Outcomes

The primary endpoint was all-cause death. Secondary endpoints were cardiac death, major adverse cardiac events (MACEs), in-hospital death, and DSWI. MACEs were defined as the composite endpoints of heart failure admissions, ischemic cardiac events, and all-cause death. Cardiac death was defined as death due to heart failure, acute myocardial infarction, lethal arrhythmia, or nontraumatic sudden death. Sudden death was defined as unexpected natural death occurring within 24 hours of onset. DSWI was defined as a sternal infection necessitating refixation of the sternum or omentoplasty.

Follow-up

Patients underwent regular follow-up at Juntendo University Hospital. Physicians assessed a patient's overall condition and reviewed the results of chest radiographs, electrocardiography, and echocardiography. Additionally, each patient completed a questionnaire on symptoms, cardiac and cerebrovascular events, cardiac-related readmissions, and cardiac interventions. Patients unable to visit the hospital were contacted by phone to inquire about their physical condition, symptoms, and any adverse events. Some patients were lost to follow-up due to relocation or non-adherence to hospital visits. The follow-up duration was defined as the period from the operation date to the date of death or the last contact. The mean follow-up period was 9.7 years.

Statistical analysis

In comparing patient characteristics, categorical data are presented as frequencies and percentages, whereas continuous variables are depicted using mean ± standard deviation (SD) or median (interquartile range). For univariable comparisons between the groups, t-tests were used for normally distributed variables and two-sample proportion tests for binary variables. Chi-squared tests were used to evaluate relationships among multivalued categorical variables. Kaplan–Meier analysis and log-rank tests were used to evaluate postoperative survival in both the entire and the propensity score-matched populations. Cox proportional hazard regression modeling was used to estimate the treatment effect and its statistical significance for cumulative survival and MACE-free survival between the BITA and ITA-RA groups. The following variables were included as covariates in multivariable models: age, sex, DM, CKD (Stages 4 and 5), cerebrovascular disease, peripheral artery disease, left ventricular ejection fraction, and the use of ITA graft.

Propensity score matching was used to reduce selection bias in assigning patients to specific grafts when comparing second arterial graft outcomes in the BITA and ITA-RA groups (**Supplementary File**: available online). Covariates in the logistic regression for calculating propensity scores included age, sex, CKD, cerebrovascular diseases, peripheral artery disease, DM, and left ventricular function. Statistical significance was established at $p < 0.05$, with all analyses conducted using JMP software (JMP Pro version 16; SAS Institute, Cary, NC, USA). C-statistics were used to assess the ability to accurately differentiate between the two groups, indicated by an area under the receiver operating characteristic curve of 0.613, signifying satisfactory discrimination. Standardized differences were used to assess covariate balance post-propensity score matching, considering a difference of ≤10% as ideal.[14]

Results

This study included 1722 patients who underwent isolated primary CABG between 2002 and 2012. Among them, 1676 patients underwent LITA-LAD anastomosis, including 1310 who underwent LCx revascularization. Furthermore, 520 patients who underwent LCx revascularization with an SVG or the gastroepiploic artery were excluded. In total, 790 patients fulfilled the inclusion criteria, with 548 and 242 patients in the BITA and ITA-RA groups, respectively (**Fig. 1**). The mean age was 66 (±10) years, and 18% of patients were female. The BITA group included significantly more patients with DM and patients with Stage 4 or higher CKD. A total of 240 pairs (n = 480) from the BITA and ITA-RA groups were identified by propensity score matching. After propensity score matching, the two groups were effectively balanced (**Fig. 2**). A comparison of baseline characteristics, surgical technique, and postoperative course for the entire cohort and the propensity score-matched cohort is shown in **Tables 1–3**. Details regarding graft combinations and utilization are found in **Table 4**.

Primary outcomes

Kaplan–Meier survival curves showed that the BITA group had a significantly lower mortality rate in the propensity-matched cohort (log-rank p = 0.02). In the multivariable analysis, using the Cox proportional hazards model, of the propensity-matched cohort, the BITA group exhibited a substantially lower mortality rate (hazard ratio (HR): 0.54; 95% confidence interval (CI): 0.38–0.76; p = 0.01) than the ITA-RA group. In the multivariate analysis, using the Cox proportional hazards model, of the entire cohort, the BITA group exhibited significantly lower rates of long-term all-cause mortality than the ITA-RA group (HR: 0.63; 95% CI: 0.48–0.84; p = 0.01) (**Fig. 2**, **Table 5**).

Secondary outcomes

The multivariate analysis, employing the Cox proportional hazards model, revealed a significantly lower cumulative incidence of MACEs in the BITA group than

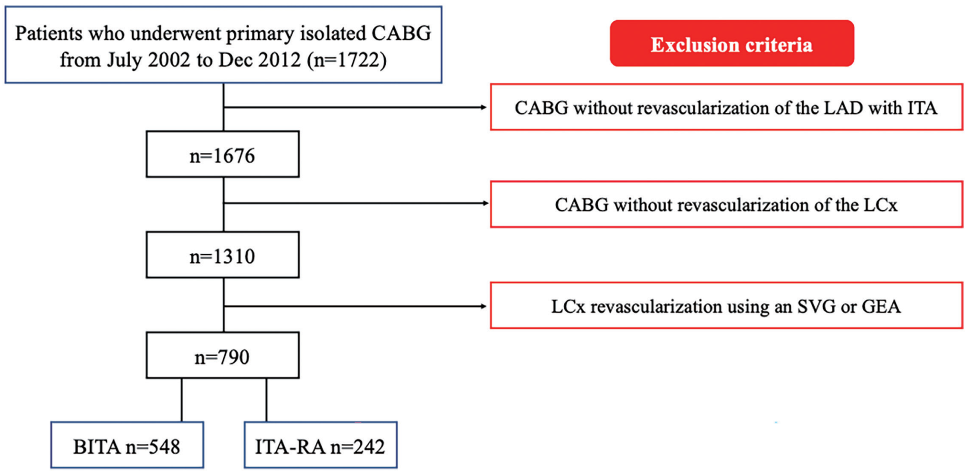

Fig. 1 Flow diagram of patient selection. CABG: coronary artery bypass grafting; LAD: left anterior descending artery; LCx: left circumflex artery; SVG: saphenous vein graft; GEA: gastroepiploic artery; ITA: internal thoracic artery; RA: radial artery; BITA: bilateral internal thoracic artery

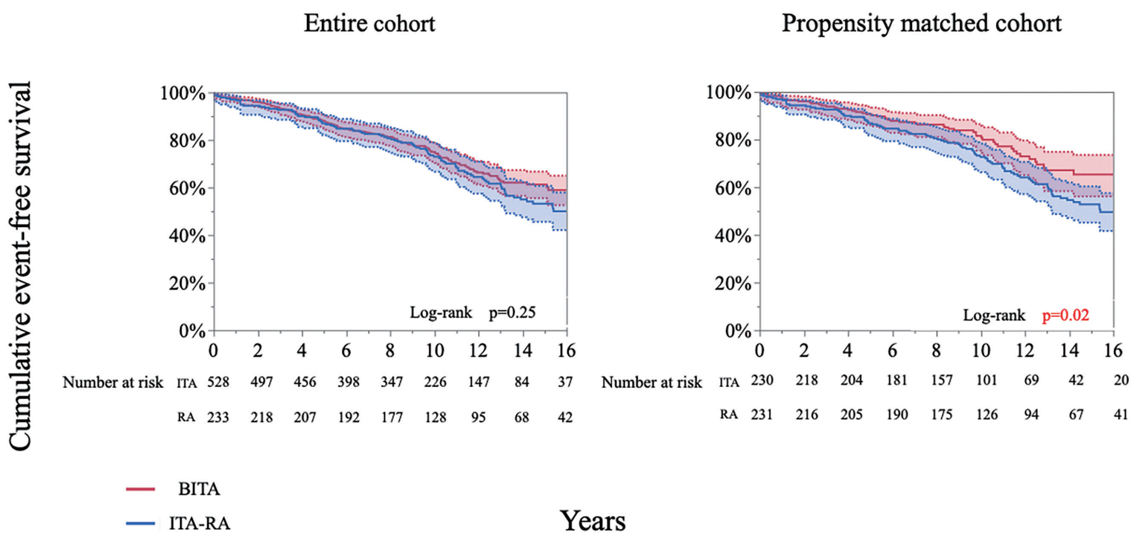

Fig. 2 Primary outcome. Kaplan–Meier survival curves were plotted for all-cause death in the entire cohort (left) and in the propensity score-matched cohort (right). The shaded areas represent the 95% confidence intervals. BITA: bilateral internal thoracic artery; ITA: internal thoracic artery; RA: radial artery

in the ITA-RA group (HR: 0.72; 95% CI: 0.55–0.93; p = 0.01). In the propensity-matched cohort, the BITA group exhibited significantly lower cumulative incidences of MACEs than the ITA-RA group (HR: 0.73; 95% CI: 0.53–0.99; p = 0.04). No significant differences in the incidences of in-hospital death and DSWI were observed between the two groups in both cohorts (**Fig. 3**, **Table 5**).

Discussion

The main finding of this study was that the ITA graft was superior to the RA graft when used as a second graft for LCx revascularization in terms of all-cause mortality over approximately 10 years in a propensity score-matched cohort. Additionally, multivariable analysis of the entire cohort revealed that the use of the BITA resulted in fewer MACEs and improved long-term mortality.

In the entire cohort, DM and CKD, known as risk factors for poor outcomes following CABG,[15,16] were more prevalent in the BITA group than in the ITA-RA group. The propensity score matching likely standardized the patient backgrounds, potentially leading to improved mortality rates in the BITA group.

Table 1 Baseline characteristics of study participants

	Entire cohort (n = 790)				Propensity score-matched cohort (n = 480)		
	BITA (n = 548)	ITA-RA (n = 242)	P-value	SMD	BITA (n = 240)	ITA-RA (n = 240)	SMD
Age (years)	66 ± 10	66 ± 9.5	0.98	<0.01	67 ± 10	66 ± 9.6	0.11
Male sex	459 (83%)	191 (79%)	0.11	0.12	194 (81%)	189 (80%)	0.05
BMI (kg/m^2)	24 ± 3.1	24 ± 2.9	0.46	0.06	24 ± 3.1	24 ± 2.9	0.04
Hypertension	403 (74%)	178 (74%)	0.93	0.02	170 (71%)	177 (74%)	0.08
Smoking history	334 (61%)	135 (57%)	0.27	0.09	144 (60%)	134 (57%)	0.07
Family history	136 (25%)	43 (18%)	0.04	0.17	53 (22%)	43 (18%)	0.10
Cerebrovascular disease	80 (15%)	40 (17%)	0.52	0.05	32 (13%)	40 (17%)	0.10
Peripheral artery disease	75 (14%)	28 (12%)	0.49	0.06	32 (13%)	28 (12%)	0.05
Diabetes	315 (58%)	116 (48%)	0.01	0.19	126 (53%)	115 (48%)	0.09
HbA1c (%)	6.2 ± 1.2	6.1 ± 1.3	0.52	0.05	6.1 ± 1.2	6.1 ± 1.3	<0.01
eGFR (mL/min/1.73 m^2)	62 ± 27	71 ± 21	<0.01	0.29	68 ± 28	73 ± 37	0.10
CKD Stage 1	312 (57%)	164 (69%)	<0.01	0.23	151 (63%)	162 (68%)	0.09
CKD Stages 2 and 3	170 (31%)	74 (31%)	0.93	<0.01	84 (35%)	74 (31%)	0.09
CKD Stages 4 and 5	66 (12%)	4 (1.7%)	<0.01	0.42	5 (2.1%)	3 (1.3%)	0.06
LDL-C ≥140 (mg/dL)	64 (12%)	31 (13%)	0.64	0.03	28 (12%)	31 (13%)	0.04
BNP (pg/mL)	66 (28–161)	56 (25–143)	0.22	0.15	57 (25–109)	57 (25–143)	0.04
LVEF (%)	56 ± 14	58 ± 14	0.05	0.15	58 ± 13	58 ± 14	0.04
LVEF <50%	175 (32%)	67 (28%)	0.24	0.09	39 (16%)	41 (17%)	0.02
Number of diseased vessels	3.3 ± 0.7	3.2 ± 0.7	0.12	0.12	3.3 ± 0.7	3.2 ± 0.7	0.12
2-vessel disease	64 (12%)	32 (13%)	0.55	0.05	34 (14%)	32 (13%)	0.03
3-vessel disease	262 (48%)	128 (53%)	0.19	0.10	103 (43%)	126 (53%)	0.19
4-vessel disease	222 (41%)	82 (34%)	0.08	0.14	103 (43%)	82 (34%)	0.18
LCx lesion							
75%	82 (15%)	49 (20%)	0.07	0.14	38 (16%)	49 (20%)	0.12
90%	237 (43%)	92 (38%)	0.18	0.11	107 (45%)	92 (38%)	0.13
99%	66 (12%)	29 (12%)	1.00	<0.01	26 (11%)	29 (12%)	0.04
100%	91 (17%)	41 (17%)	0.91	0.01	35 (15%)	40 (17%)	0.06
LMT lesion	221 (40%)	81 (33%)	0.07	0.14	103 (43%)	80 (38%)	0.20
LAD >75%	492 (90%)	217 (90%)	1.00	<0.01	223 (93%)	216 (90%)	0.10
Dx >75%	190 (35%)	92 (38%)	0.38	0.07	73 (30%)	92 (38%)	0.94
RCA >75%	426 (78%)	191 (79%)	0.71	0.04	171 (71%)	190 (79%)	0.18
Euro SCORE (%)	1.5 (1.0–2.6)	1.3 (0.8–2.0)	0.57	0.07	1.4 (0.9–2.3)	1.4 (0.8–2.0)	0.02
Japan Score (%)	0.9 (0.6–1.5)	0.8 (0.5–1.2)	0.31	0.12	0.9 (0.6–1.2)	0.8 (0.5–1.2)	0.10

Unless indicated otherwise, data are presented as the mean ± standard deviation, median (interquartile range), or n (%).
BITA: bilateral internal thoracic artery; ITA: internal thoracic artery; RA: radial artery; SMD: standardized mean difference; BMI: body mass index; HbA1c: hemoglobin A1c; LDL-C: low-density lipoprotein cholesterol; eGFR: estimated glomerular filtration rate; BNP: brain natriuretic peptide; LVEF: left ventricular ejection fraction; LMT: left main trunk; RCA: right coronary artery; LCx: left circumflex artery

There are several past studies[5–9] that have compared the BITA and ITA-RA. The Arterial Revascularization Trial was the first randomized controlled study to compare 10-year survival between using a single ITA and BITA. This was a landmark study that could eliminate selection bias; however, in many patients, grafts different from the assigned grafts were used. While there was no significant difference in long-term survival between the two groups, in the intention-to-treat group, the long-term outcome of the BITA group was superior to that of the as-treated group.[17,18] The Radial Artery Patency and Clinical Outcomes trial, a prospective randomized controlled trial, compared the use of the RA and the ITA anastomosed to the aorta as inflow conduits.[19] In this trial, the RA graft was associated with better 10-year estimated survival; however, the LCx revascularization

Table 2 Operative outcomes

	Entire cohort (n = 790)				Propensity score-matched cohort (n = 480)		
	BITA (n = 548)	ITA-RA (n = 242)	p-value	SMD	BITA (n = 240)	ITA-RA (n = 240)	SMD
OPCAB	542 (99%)	234 (96%)	<0.01	0.21	239 (99.6%)	229 (97.5%)	0.27
Operative time (min)	311 ± 78	332 ± 86	<0.01	0.26	306 ± 77	333 ± 85	0.33
Preoperative IABP	18 (3.3%)	15 (6.2%)	0.08	0.14	8 (3.3%)	15 (6.3%)	0.14
Emergency	28 (5.1%)	26 (11%)	<0.01	0.21	15 (6.3%)	26 (11%)	0.16
RITA-LAD	67 (12%)	8 (3.3%)	<0.01	0.34	30 (13%)	8 (3.3%)	0.34
Other graft selection							
Gastroepiploic artery	195 (36%)	124 (51%)	<0.01	0.31	80 (33%)	123 (51%)	0.37
Saphenous vein	197 (36%)	54 (22%)	<0.01	0.30	78 (33%)	54 (23%)	0.23
Central anastomosis	242 (44%)	176 (73%)	<0.01	0.60	100 (42%)	175 (73%)	0.67
Composite graft	144 (26%)	80 (33%)	0.06	0.15	61 (25%)	79 (33%)	0.17
I-graft	26 (4.7%)	16 (6.6%)	0.30	0.08	15 (6.3%)	14 (5.8%)	0.02
Y-graft	118 (22%)	65 (27%)	0.12	0.12	46 (19%)	65 (27%)	0.19

Unless indicated otherwise, data are presented as the mean ± SD or n (%).
BITA: bilateral internal thoracic artery; ITA: internal thoracic artery; RA: radial artery; SMD: standardized mean difference; OPCAB: off-pump coronary artery bypass grafting; RITA: right internal thoracic artery; LAD: left anterior descending artery; IABP: intra-aortic balloon pumping

Table 3 Postoperative outcomes

	Entire cohort (n = 790)				Propensity score-matched cohort (n = 480)		
	BITA (n = 548)	ITA-RA (n = 242)	p-value	SMD	BITA (n = 240)	ITA-RA (n = 240)	SMD
Hospital stay (days)	11 ± 8.7	12 ± 7.3	0.47	0.06	11 ± 6.6	12 ± 7.3	0.11
ICU stay (days)	1.6 ± 1.6	2.5 ± 5.4	<0.01	0.24	1.5 ± 1.6	2.5 ± 5.3	0.25
Postoperative stroke	8 (1.5%)	6 (2.5%)	0.38	0.14	5 (2.1%)	5 (2.1%)	<0.01
Respiratory failure	7 (1.3%)	4 (1.7%)	0.74	0.03	3 (1.3%)	4 (1.7%)	0.03
Acute kidney injury	29 (5.3%)	6 (2.5%)	0.09	0.15	11 (4.6%)	6 (2.5%)	0.11
POAF	143 (26%)	50 (21%)	0.11	0.13	49 (20%)	34 (14%)	0.13

Unless indicated otherwise, data are presented as the mean ± SD or n (%).
BITA: bilateral internal thoracic artery; ITA: internal thoracic artery; RA: radial artery; SMD: standardized mean difference; ICU: intensive care unit; POAF: postoperative atrial fibrillation

Table 4 Internal thoracic artery (ITA) and radial artery (RA) arrangement

		Entire cohort (n = 790)	Propensity score-matched cohort (n = 480)
RITA (n = 548)			
In situ		427 (78%)	193 (80%)
In situ	RITA-LCx	401 (73%)	178 (74%)
In situ I composite	RITA-I composite graft—LCx	26 (4.7%)	15 (6.2%)
Y composite	LITA-LAD – free RITA (Y composite graft)—LCx	118 (22%)	46 (19%)
Others		3 (0.5%)	1 (0.4%)
RA (n = 242)			
Ao-RA	Ao-RA	162 (67%)	161 (67%)
LITA Y composite	LITA-LAD – RA (Y composite graft)—LCx	61 (25%)	60 (25%)
GEA Y composite	GEA-RCA – RA (Y composite graft)—LCx	4 (1.7%)	4 (1.7%)
Others		15 (6%)	15 (6%)

Unless indicated otherwise, data are presented as n (%).
RITA: right internal thoracic artery; LCx: left circumflex artery; LAD: left anterior descending artery; RA: radial artery; Ao: aorta; LITA: left internal thoracic artery; GEA: gastroepiploic artery; RCA: right coronary artery

Table 5 Study outcomes

	Entire cohort (n = 790)				Propensity score-matched cohort (n = 480)			
	BITA (n = 548)	ITA-RA (n = 242)	Adjusted RR (95% CI)	p-value	BITA (n = 240)	ITA-RA (n = 240)	Adjusted RR (95% CI)	p-value
Primary outcome								
All-cause death	151 (29%)	94 (40%)	0.63 (0.48–0.84)[A]	0.01	53 (23%)	94 (41%)	0.54 (0.38–0.76)[A]	0.01
Secondary outcomes								
MACEs	96 (18%)	52 (22%)	0.72 (0.55–0.93)[A]	0.01	42 (18%)	53 (23%)	0.73 (0.53–0.99)[A]	0.04
Cardiac death	29 (5.3%)	17 (7.0%)	0.66 (0.34–1.28)[A]	0.22	11 (4.6%)	17 (7.1%)	0.60 (0.27–1.31)[A]	0.20
In-hospital death	7 (1.3%)	2 (0.8%)	0.64 (0.13–3.12)[B]	0.73	1 (0.4%)	2 (0.8%)	2.01 (0.18–22.3)[B]	1.00
DSWI	7 (1.3%)	1 (0.4%)	0.32 (0.04–2.62)[B]	0.45	3 (1.3%)	1 (0.4%)	0.33 (0.03–3.20)[B]	0.62

Unless indicated otherwise, data are presented as n (%).
[A]Hazard ratio (95% CI).
[B]Odds ratio (95% CI).
BITA: bilateral internal thoracic artery; ITA: internal thoracic artery; RA: radial artery; RR: relative risk; CI: confidence interval; MACEs: major adverse cardiac events; DSWI: deep sternal wound infection

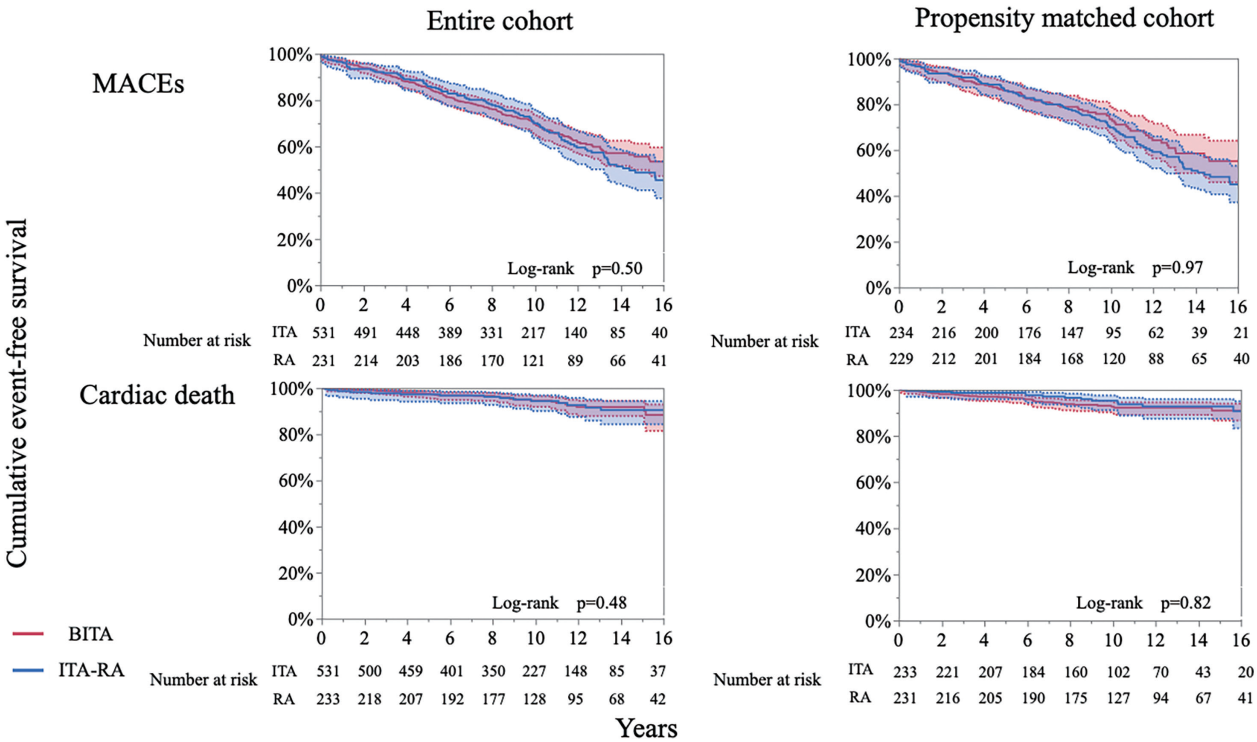

Fig. 3 Secondary outcomes. Kaplan–Meier survival curves were plotted for MACEs and cardiac death in the entire cohort (left) and in the propensity score-matched cohort (right). The shaded areas represent the 95% confidence intervals. BITA: bilateral internal thoracic artery; ITA: internal thoracic artery; RA: radial artery; MACEs: major adverse cardiac events

rate using the RA graft was only 70%, the graft was also anastomosed to the RCA, and ITA grafts were used in all aortocoronary bypass grafts. Owing to the differences in target vessels and the fact that all ITAs were anastomosed to the aorta as free grafts, the results of this study are entirely distinct and not comparable.

Tsuneyoshi et al. reported that the RA anastomosed to the aorta is comparable to the RITA as the second arterial graft in a 5-year follow-up in Japanese participants.[13] Three potential reasons for these differing results include the following: (i) inclusion of patients with CKD, (ii) use of composite grafts, and (iii) RA grafts harvested using the skeletonized technique. Composite grafts compete for blood flow based on the target vessel's stenosis rate, potentially influencing patency. In this study, composite grafts tended to be used more in the ITA-RA group than the BITA group, which may have affected the long-term outcome of the RA graft.

When comparing the RA and the ITA, the biophysiological differences could not be ignored. There are some differences in the arterial wall structure and muscular tonus between elastic arteries and muscular arteries. In contrast to the ITA, which is an elastic artery and less prone to late degeneration, muscular arteries, known to be susceptible to late degeneration, might not show a significant difference in mortality rates between the RA and ITA unless the follow-up period exceeds 10 years, rather than being just a few years. Bakaeen et al. reported that using the BITA improved long-term survival by maximizing the area of the myocardium supplied by the ITA[20]; this finding is consistent with the results of the present study. It is conceivable that a skeletonized RA is associated with poorer long-term outcomes, and the maximized revascularization area of an ITA might lead to a significant survival difference between the BITA and ITA-RA; however, further research is required.

When using the BITA, concerns remain regarding the increased risk of DSWI due to reduced blood flow to the sternum. However, the safety of BITA skeletonization was previously reported in a meta-analysis by Gaudino et al.,[12] who concluded that the risk of DSWI is not significantly increased by harvesting the ITA using the skeletonizing technique. In a sub-analysis of the Arterial Revascularization Trial, the risk of DSWI was similar between using a skeletonized BITA or a non-skeletonized SITA, and a skeletonized BITA was relatively safe.[21] In this study, there was no significant difference between the BITA and ITA-RA groups in the development of DSWI; the five steps used to prevent DSWI in this study may have contributed to this result.

Limitations

Bias in graft selection cannot be ruled out owing to the retrospective nature of this study. Although the propensity score matching analysis resulted in comparable groups, the study was not randomized; therefore, additional effects from missing covariates cannot be excluded. In observational studies of CABG, limitations, including the inability to eliminate surgeon's preferences and third graft mismatches, often exist, even with the use of propensity score matching. Given that this was a retrospective study with 10 years of follow-up, there were interruptions in the follow-up, and the incidence of cardiovascular events may not be all-inclusive. In general, the prognosis after CABG is probably attributable to graft patency. However, graft patency assessment was impossible in this study because we did not perform routine coronary computed tomography angiography or follow-up coronary angiography. Therefore, the prognostic value of graft patency could not be determined, and the reason for the significant difference in this hard endpoint could not be determined. Consequently, further investigations are necessary.

Conclusions

This study suggests that CABG using the ITA as the secondary arterial graft for LCx revascularization significantly reduces all-cause mortality over approximately 10 years compared to that using the RA without increasing the risk of in-hospital mortality or DSWI. Consequently, the use of the ITA as a second arterial graft for LCx revascularization may provide superior outcomes compared to the use of RA.

Declarations

Ethics approval and consent to participate

All study protocols were approved by the Research Ethics Committee of the Faculty of Medicine at Juntendo University on April 21, 2022 (approval no. E22-0096-H01). The need for informed consent was waived owing to the retrospective nature of this study.

Funding

None.

Data availability statement

The deidentified participant data will not be shared.

Disclosure statement

The authors declare that there are no conflicts of interest.

Supplementary File

Propensity score matching

The blue bars represent the BITA group, and the red bars represent the ITA-RA group. The graph on the left side shows before score propensity matching, and that on the right side shows after propensity score matching. Abbreviations: BITA, bilateral internal thoracic artery; RA, radial artery

References

1) Loop FD, Lytle BW, Cosgrove DM, et al. Influence of the internal-mammary-artery graft on 10-year survival and other cardiac events. N Engl J Med 1986; **314**: 1–6.
2) Cameron A, Davis KB, Green G, et al. Coronary bypass surgery with internal-thoracic-artery grafts--effects on survival over a 15-year period. N Engl J Med 1996; **334**: 216–9.
3) Neumann FJ, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J 2019; **40**: 87–165.
4) Lawton JS, Tamis-Holland JE, Bangalore S, et al. 2021 ACC/AHA/SCAI guideline for coronary artery revascularization: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation 2022; **145**: e4–17.
5) Ruttmann E, Fischler N, Sakic A, et al. Second internal thoracic artery versus radial artery in coronary artery bypass grafting: a long-term, propensity score-matched follow-up study. Circulation 2011; **124**: 1321–9.
6) Benedetto U, Raja SG, Albanese A, et al. Searching for the second best graft for coronary artery bypass surgery: a network meta-analysis of randomized controlled trials. Eur J Cardiothorac Surg 2015; **47**: 59–65; discussion, 65.
7) Schwann TA, Hashim SW, Badour S, et al. Equipoise between radial artery and right internal thoracic artery as the second arterial conduit in left internal thoracic artery-based coronary artery bypass graft surgery: a multi-institutional study. Eur J Cardiothorac Surg 2016; **49**: 188–95.
8) Raja SG, Benedetto U, Jothidasan A, et al. Right internal mammary artery versus radial artery as second arterial conduit in coronary artery bypass grafting: a case-control study of 1526 patients. Int J Surg 2015; **16**(Pt B): 183–9.
9) Schwann TA, Habib RH, Wallace A, et al. Bilateral internal thoracic artery versus radial artery multi-arterial bypass grafting: a report from the STS databasese. Eur J Cardiothorac Surg 2019; **56**: 926–34.
10) Lytle BW, Blackstone EH, Sabik JF, et al. The effect of bilateral internal thoracic artery grafting on survival during 20 postoperative years. Ann Thorac Surg 2004; **78**: 2005–12; discussion, 2012ra.
11) Suzuki T, Asai T, Matsubayashi K, et al. In off-pump surgery, skeletonized gastroepiploic artery is superior to saphenous vein in patients with bilateral internal thoracic arterial grafts. Ann Thorac Surg 2011; **91**: 1159–64.
12) Gaudino M, Puskas JD, Di Franco A, et al. Three arterial grafts improve late survival: a meta-analysis of propensity-matched studies. Circulation 2017; **135**: 1036–44.
13) Tsuneyoshi H, Komiya T, Shimamoto T, et al. The second best arterial graft to the left coronary system in off-pump bypass surgery: a propensity analysis of the radial artery with a proximal anastomosis to the ascending aorta versus the right internal thoracic artery. Gen Thorac Cardiovasc Surg 2015; **63**: 335–42.
14) Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. Stat Med 2009; **28**: 3083–107.
15) Cooper WA, O'Brien SM, Thourani VH, et al. Impact of renal dysfunction on outcomes of coronary artery bypass surgery: results from the Society of Thoracic Surgeons National Adult Cardiac Database. Circulation 2006; **113**: 1063–70.
16) Gallagher S, Kapur A, Lovell MJ, et al. Impact of diabetes mellitus and renal insufficiency on 5-year mortality following coronary artery bypass graft surgery: a cohort study of 4869 UK patients. Eur J Cardiothorac Surg 2014; **45**: 1075–81.
17) Taggart DP, Benedetto U, Gerry S, et al. Bilateral versus single internal-thoracic-artery grafts at 10 years. N Engl J Med 2019; **380**: 437–46.
18) Taggart DP. Implications of the 10-year outcomes of the Arterial Revascularization trial (ART) for multiple arterial grafts during coronary artery bypass graft. Eur J Cardiothorac Surg 2019; **56**: 427–8.
19) Buxton BF, Hayward PA, Raman J, et al. Long-term results of the RAPCO trials. Circulation 2020; **142**: 1330–8.
20) Bakaeen FG, Ravichandren K, Blackstone EH, et al. Coronary artery target selection and survival after bilateral internal thoracic artery grafting. J Am Coll Cardiol 2020; **75**: 258–68.
21) Benedetto U, Altman DG, Gerry S, et al. Pedicled and skeletonized single and bilateral internal thoracic artery grafts and the incidence of sternal wound complications: insights from the Arterial Revascularization Trial. J Thorac Cardiovasc Surg 2016; **152**: 270–6.