Clinical Research

Effect of the Proximal Anastomosis Configuration of the Radial Artery in Patients Undergoing Coronary Artery Bypass Grafting

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Background: Several factors, such as the degree of target vessel stenosis, are known to be associated with radial artery (RA) graft patency in coronary artery bypass grafting (CABG). There is a lack of data regarding the effect of the RA proximal configuration (aortic anastomosis versus T-anastomosis). This study evaluated the effects of the RA proximal configuration on the patency rate and clinical outcomes after CABG.
Methods: We conducted a retrospective study, analyzing 328 patients who had undergone CABG with an RA graft. We divided the patients into 2 groups. The primary endpoint was RA patency and the secondary endpoints were overall mortality and major adverse cardiac and cerebrovascular events (MACCE). We performed a propensity score-matched comparison.
Results: Aorta-RA anastomosis was performed in 275 patients, whereas the rest of the 53 patients received T-RA anastomosis. The mean age was 67.3±8.7 years in the T-RA anastomosis group and 63.8±9.5 years in the aorta-RA anastomosis group (p=0.02). The mean follow-up duration was 5.13±3.07 years. Target vessel stenosis ≥70% (hazard ratio [HR], 0.42; 95% confidence interval [CI], 0.20–0.91; p=0.03) and T-RA anastomosis configuration (HR, 2.34; 95% CI, 1.01–5.19; p=0.04) were significantly associated with RA occlusion in the multivariable analysis. However, T-RA anastomosis was not associated with higher risks of overall mortality and MACCE following CABG (p=0.30 and p=0.07 in the matched group, respectively).
Conclusion: Aorta-RA anastomosis showed a superior patency rate compared to T-RA anastomosis. However, the RA proximal anastomosis configuration was not associated with mortality or MACCE.

Keywords: Coronary artery bypass grafting, Radial artery, Vascular patency, Vascular graft occlusion, Surgical anastomosis

Introduction

Coronary artery bypass grafting (CABG) is the treatment of choice for patients with multi-vessel coronary artery disease or left main coronary artery stenosis [1]. Studies have been conducted over recent decades to improve the patency of bypass grafts and to identify the preferred conduit selection, since long-term outcomes are mainly determined by the patency of the bypass grafts used during surgery [2-5]. Using the internal mammary artery (IMA) is known to be the gold standard for conduit selection, and it is highly recommended for grafting the left anterior descending artery (LAD) [6]. However, the selection of the second graft is still controversial. As a second graft, many studies demonstrated superior patency rates of radial artery (RA) grafts compared to saphenous vein grafts (SVGs) [2,7-9]. Deb et al. [8] showed that the occlusion rate of the RA was 8.9% (n=269), whereas that of the saphenous vein was 18.6% (n=269) over 7.7±1.5 years. Factors such as age, sex, target vessel stenosis, target vessel territory, and graft proximal configuration were suggested as risk factors for RA occlusion [10-17]. Among these factors, the configuration of the proximal anastomosis of RA (direct aorta-RA anastomosis or T-RA anastomosis) remains debatable [10-14,18] and only limited data are available. Therefore, we conducted this study to identify the effects of the RA prox-

imal configuration on the patency rate and clinical outcomes after CABG.

Methods

Patients

From January 2010 to August 2018, a total of 874 patients underwent CABG at Seoul St. Mary's Hospital, Seoul, Republic of Korea. We retrospectively reviewed 328 consecutive patients with an RA conduit and excluded patients who were unsuitable for RA grafting due to a positive modified Allen's test, advanced chronic kidney disease (≥stage 4), or a history of forearm ischemia/trauma (Fig. 1). The data were collected from our thoracic and cardiovascular surgery database and electronic medical records. Follow-up completeness was 97.3%, with a median follow-up duration of 60.25 months (interquartile range [IQR], 28.96–98.43 months). We excluded 34 of the 328 patients from the analysis of RA patency because no follow-up examinations had been performed to confirm patency postoperatively. As the primary interest of our study was to compare the clinical outcomes according to the type of proximal anastomosis of the RA, we divided patients into 2 groups: the aorta-RA anastomosis group and the T-RA anastomosis group. The primary endpoint was RA patency after CABG. Secondary endpoints included overall mortality and major adverse cardiac and cerebrovascular events

(MACCE) (defined as death, myocardial infarction, cerebrovascular accident [CVA], or target vessel revascularization). The institutional review board of the Catholic University College of Medicine approved the study protocol (KC20RASI0500), and the requirement for individual patient consent was waived.

Surgical strategy

At our institution, we primarily perform on-pump CABG if computed tomography (CT) findings do not rule out cannulation and cross-clamping of the aorta. We considered either on-pump CABG or off-pump CABG, depending on the degree of calcification of the ascending aorta. The left IMA (LIMA) was the first choice of conduit to revascularize the LAD territory, except in contraindicated circumstances. For non-LAD territory, we selected the RA over the SVG, especially for left circumflex territory.

We harvested the RA in a pedicle method, using a Harmonic scalpel (Ethicon Endo Surgery, Cincinnati, OH, USA) to minimize arterial wall damage. After harvesting, we stored the RA in papaverine solution until anastomosis. During the operative and perioperative periods, we administered an intravenous calcium channel blocker (CCB) and nitroglycerine to prevent vasospasms and to induce vasodilation. We then switched to oral CCB and isosorbide dinitrate when oral intake became possible. These medications were continued for more than 1 year postoperatively.
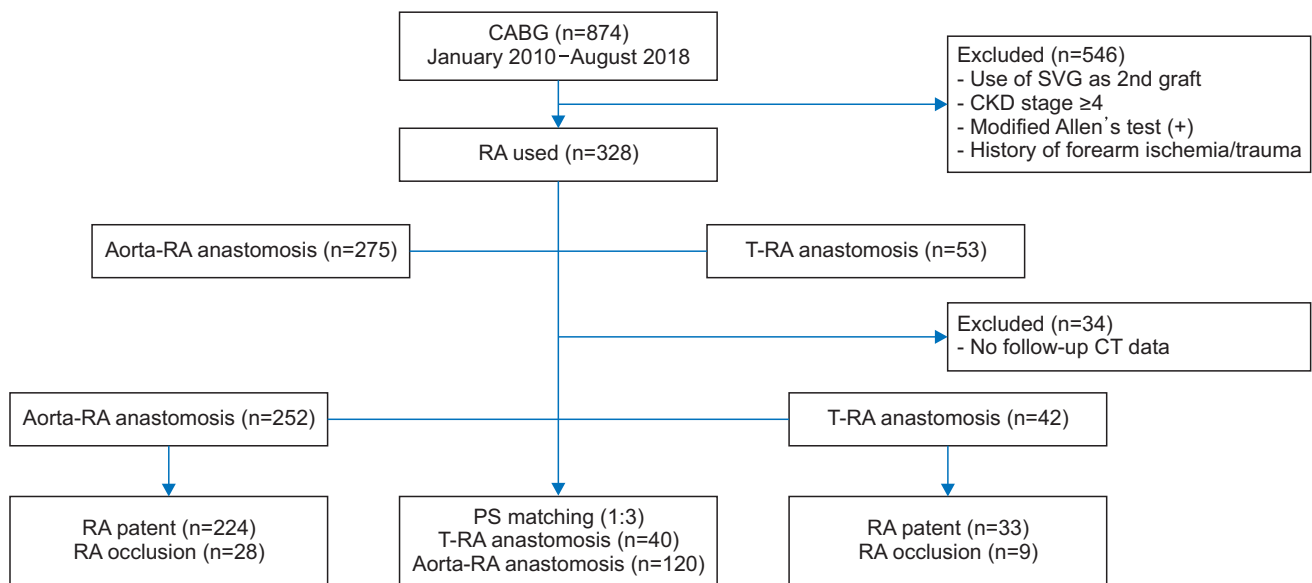

Fig. 1. Flow chart of patient selection. CABG, coronary artery bypass grafting; CKD, chronic kidney disease; CT, computed tomography; PS, propensity score; RA, radial artery; SVG, saphenous vein graft.

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We anastomosed the RA proximally to either the LIMA or SVG as a composite T-graft, or to the ascending aorta. We used continuous 7-0 polypropylene sutures to perform the anastomosis between the aorta and the RA, and continuous 8-0 polypropylene sutures to perform the distal and the T-RA anastomoses. Generally, we preferred aorta-RA anastomoses unless the RA graft was of insufficient length or if there was severe calcification around the aortic anastomosis site.

Follow-up and definition of radial artery patency

Data collection was performed until February 2020 via direct telephone interviews and a detailed review of all medical records. The date of death in mortality cases were confirmed using information from the National Health Insurance Service.

For the assessment of graft patency, we performed postoperative CT before discharge, 1 year following surgery, and then, every 2 years following surgery. In patients who had poor kidney function (glomerular filtration rate <50 mL/min/1.73 m^2), we did not perform follow-up CT. We performed coronary angiography in patients who had significant stenotic findings on CT, new-onset angina, or abnormal findings on cardiac echocardiography during follow-up. We based our definition of occlusion on the Fitzgibbon classification, and we considered grade O to indicate graft occlusion [19]. The degree of target vessel stenosis in patients undergoing sequential anastomosis was defined by a higher degree of stenosis on angiographic findings between the 2 target vessels.

Statistical analysis

We performed all statistical analyses using IBM SPSS ver. 24.0 (IBM Corp., Armonk, NY, USA). We summarized all data as the mean±standard deviation or as the median and IQR for continuous variables and the frequency and the percentage of categorical variables as appropriate. We compared the clinical characteristics between the aorta-RA anastomosis and T-RA anastomosis groups, using the Student t-test for the mean of normally distributed continuous variables and the Mann-Whitney U-test for non-parametric skewed distributions. All categorical variables were compared between the 2 groups using the chi-square test or Fisher exact test. To identify risk factors for RA occlusion, mortality, and MACCE, we performed univariable and multivariable analyses using Cox proportional hazard models. The proportional hazards assumption was tested

using log-minus-log curves. We found that the assumption of proportional hazards was not violated.

For the multivariable analyses, the variables assessed in univariable models were included in the final multivariable analyses based on their clinical importance if they had a p-value <0.1 in the univariable analysis.

To reduce the effect of treatment-selection bias and potential confounders in this observational study, we performed a rigorous adjustment for significant differences in the baseline patient characteristics using propensity score matching. A propensity score was generated for each patient from a multivariable logistic regression model based on 19 preoperative characteristics as independent variables (Tables 1, 2). We assessed the discrimination and calibration abilities of the model using the C and Hosmer-Lemeshow statistics. We matched the T-RA anastomosis group with the aorta-RA anastomosis group in a 1:3 (maximum) ratio using a greedy matching algorithm (the nearest-neighbor matching method). The risk of each outcome was compared using a Cox regression model with generalized estimating equations in the propensity score-matched cohort.

Using the Kaplan-Meier method, we assessed freedom from RA occlusion for each anastomosis configuration. We performed inter-group comparisons using the log-rank test and Prentice-Wilcoxon test as appropriate.

Results

Patient characteristics

Among the 328 patients, aorta-RA anastomosis was performed in 275 patients, whereas the rest of the 53 patients received T-RA anastomosis. The baseline characteristics of the patients were summarized in Tables 1 and 2. The mean age was 67.3±8.7 years in the T-RA anastomosis group and 63.8±9.5 years in the aorta-RA anastomosis group (p=0.02). The T-RA anastomosis group had a higher proportion of patients with dyslipidemia (30.2% versus 18.5%, p=0.05) and a longer cardiopulmonary bypass time (95.67±58.50 versus 77.09±25.74 minutes, p=0.03).

Postoperative results

In the unmatched population, the T-RA anastomosis group had a statistically significantly higher rate of re-operation due to bleeding (p=0.03) The overall RA patency rate was 87.4% (n=294) during the median follow-up duration of CT scans of 14.73 months (IQR, 5.3–55.1 months). The T-RA anastomosis group showed a higher RA occlu-

Table 1. General preoperative patient characteristics (unmatched)

Characteristic	T-RA anastomosis (n=53)	Aorta-RA anastomosis (n=275)	p-value
Age (yr)	67.3±8.7	63.8±9.5	0.02
Sex (male)	35 (66.0)	195 (70.9)	0.48
Diagnosis			0.03
Stable angina	38 (71.7)	128 (46.5)	
Unstable angina	9 (17.0)	98 (35.6)	
Acute myocardial infarction	6 (11.3)	49 (17.8)	
Preoperative ejection fraction (%)	53.7±12.3	56.0±11.8	0.20
Three-vessel disease	45 (84.9)	211 (76.7)	0.13
Comorbidity			
Hypertension	25 (47.2)	174 (63.3)	0.03
Diabetes mellitus	14 (26.4)	108 (39.3)	0.08
Dyslipidemia	16 (30.2)	51 (18.5)	0.05
Current smoker	8 (15.1)	54 (19.6)	0.44
Cerebrovascular accident	6 (11.3)	26 (9.5)	0.68
Chronic kidney disease (stage 2 or 3)	39 (73.6)	186 (67.6)	0.39
Atrial fibrillation	2 (3.8)	10 (3.6)	0.96
Target vessel stenosis (%)			0.98
<70	7 (13.2)	36 (13.1)	
≥70	46 (86.8)	239 (86.9)	
Laboratory findings			
Preoperative creatinine (mg/dL)	0.95±0.28	0.93±0.27	0.58
Preoperative hemoglobin (g/dL)	12.80±1.86	12.96±1.81	0.56
Preoperative C-reactive protein (mg/L)	0.60±1.20	0.70±1.50	0.66

Values are presented as mean±standard deviation or number (%).
RA, radial artery.

Table 2. General patient characteristics: operative profiles (unmatched)

Characteristic	T-RA anastomosis (n=53)	Aorta-RA anastomosis (n=275)	p-value
Emergency	1 (1.9)	21 (7.6)	0.13
Cardiopulmonary bypass strategy			<0.001
On-pump	38 (71.7)	269 (97.8)	
On-pump, beating	14 (26.4)	3 (1.1)	
Off-pump	1 (1.9)	3 (1.1)	
No. of distal anastomoses	2.7±0.7	2.79±0.69	0.61
Cardiopulmonary bypass time	95.7±58.5	77.1±25.7	0.03
Target vessel stenosis (%)	85.0±16.6	83.5±15.8	0.52
Total arterial revascularization	17 (32.1)	104 (37.8)	0.53
Target vessel diameter (mm)	1.5±0.1	1.5±0.2	0.28
Distal territory of radial artery			0.37
Left anterior descending artery	12 (20.0)	88 (28.5)	
Left circumflex artery	40 (66.7)	179 (57.9)	
Right coronary artery	8 (13.3)	42 (13.6)	
Sequential RA graft[a]	7 (13.2)	34 (12.4)	0.87

Values are presented as number (%) or mean±standard deviation.
RA, radial artery.
[a]The entire target territory of the sequential graft was included. There was only 1 RA occlusion in the T-RA anastomosis group, and no cases of RA occlusion in the aorta-RA anastomosis group.

sion rate than the aorta-RA anastomosis group (21.4% versus 11.1%, p=0.06) (Table 3). The follow-up rate of CT scans at each time point was 77.4%, 47.7%, and 54.5% after 1 years, 3 years, and 5 years, respectively. The follow-up duration also demonstrated a difference between the groups (p=0.02). There was no difference between the 2

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Table 3. General postoperative patient characteristics (unmatched)

Characteristic	T-RA anastomosis (n=53)	Aorta-RA anastomosis (n=275)	p-value
Early outcomes[a]			
In-hospital mortality	2 (3.8)	5 (5.9)	0.37
Re-exploration for bleeding	6 (15.1)	11 (4.0)	0.03
Wound problem	5 (9.4)	23 (8.4)	0.80
Postoperative arrhythmia	5 (9.4)	25 (9.1)	0.94
Renal replacement therapy	3 (5.7)	9 (3.3)	0.40
Stroke	1 (1.9)	4 (1.5)	0.16
Late outcomes[a]			
Stroke	0	3 (1.79)	0.59
Target vessel revascularization	1 (3.62)	1 (0.60)	0.30
Death from any cause	11 (39.60)	38 (22.56)	0.20
Myocardial infarction	1 (3.62)	1 (0.60)	0.30
Radial artery graft occlusion[b]	9 (45.65)	28 (18.99)	0.06
Left anterior descending artery	1 (11.1)	8 (28.6)	
Left circumflex artery	5 (55.6)	13 (46.4)	
Right coronary artery	3 (33.3)	7 (25.0)	
LIMA graft occlusion[c]	4 (22.43)	11 (7.35)	0.11
Follow-up duration (day)	679.17±778.75	1,005.39±1,001.91	0.02

Values are presented as number (%) or mean±standard deviation.
LIMA, left internal mammary artery; RA, radial artery.
[a]Early outcomes: number of events (%), late outcomes: number of events (/1,000 patient-years). [b]The analysis was performed on 294 patients who underwent follow-up computed tomography or coronary angiography (T-RA anastomosis: n=42, aorta-RA anastomosis: n=252). [c]The analysis was performed on 283 patients who underwent coronary artery bypass grafting with LIMA and RA grafts (T-RA anastomosis: n=37, aorta-RA anastomosis: n=246).

groups in stroke or all-cause mortality (p=0.59 and p=0.20, respectively). We matched 40 T-RA anastomosis patients with 120 aorta-RA anastomosis patients at a 1:3 ratio (Supplementary Table 1).

Risk factor analysis for radial artery occlusion

In the unmatched population, the univariable analysis showed that age (hazard ratio [HR], 1.04; 95% confidence interval [CI], 1.00–1.08; p=0.04) and the T-RA anastomosis configuration (HR, 3.02; 95% CI, 1.39–6.58; p=0.005) were risk factors for RA occlusion. Target vessel stenosis ≥70% was also related to RA patency (HR, 0.40; 95% CI, 0.19–0.86; p=0.02) [20]. The multivariable analysis demonstrated that target vessel stenosis ≥70% (HR, 0.42; 95% CI, 0.20–0.91; p=0.03) and the T-RA anastomosis configuration (HR, 2.34; 95% CI, 1.01–5.19; p=0.04) were significant predictors of RA occlusion (Table 4).

Freedom from RA occlusion was found in 91.3%, 88.5%, and 82.8% of patients after 2 years, 4 years, and 6 years, respectively, in the aorta-RA group, whereas freedom from RA occlusion was observed in 85.4%, 63.2%, and 37.9%, respectively, in the T-RA group (p=0.002) (Fig. 2A). In the matched cohort, freedom from RA occlusion was higher in aorta-RA group, as shown in Fig. 2B (p=0.003).

Risk factor analysis for overall mortality

The configuration of the proximal anastomosis was not implicated in overall mortality (p=0.11) (Table 5). The multivariable analysis showed that preoperative ejection fraction (HR, 0.97; 95% CI, 0.95–0.99; p=0.002), preoperative hemoglobin (HR, 0.77; 95% CI, 0.67–0.89; p<0.001) and preoperative C-reactive protein levels (HR, 1.20; 95% CI, 1.06–1.36; p=0.01) were related to overall mortality. There were no significant differences between groups in terms of freedom from mortality in the matched patients (p=0.50) (Fig. 3A).

Risk factor analysis for major adverse cardiac and cerebrovascular events

The configuration of RA was marginally statistically associated with MACCE (p=0.06) in the univariable analysis. However, the multivariable analysis showed no significant associations (p=0.17). Preoperative ejection fraction was linked to MACCE (HR, 0.97; 95% CI, 0.95–0.99; p=0.001). Preoperative hemoglobin was also an important factor associated with MACCE (HR, 0.76; 95% CI, 0.67–0.87; p<0.001) (Table 6). There were no significant findings between groups concerning freedom from MACCE in the matched patients (p=0.16) (Fig. 3B).

Table 4. Risk factors for occlusion of the radial artery graft in unmatched patients

Variable	Univariable		Multivariable	
	HR (95% CI)	p-value	HR (95% CI)	p-value
Age (yr)	1.04 (1.00–1.08)	0.04	1.04 (0.99–1.08)	0.10
Female	1.11 (0.56–2.19)	0.77		
Diagnosis				
Stable angina	1			
Unstable angina	0.68 (0.25–1.83)	0.44		
Acute myocardial infarction	1.10 (0.53–2.26)	0.80		
Preoperative ejection fraction (%)	1.01 (0.98–1.04)	0.58		
Hypertension	1.28 (0.64–2.56)	0.49		
Diabetes mellitus	1.89 (0.98–3.63)	0.06		
Dyslipidemia	1.85 (0.87–3.97)	0.11		
Current smoker	1.08 (0.47–2.46)	0.86		
Chronic kidney disease	2.50 (1.09–5.71)	0.03		
Cerebrovascular accident	1.06 (0.37–3.01)	0.91		
Preoperative creatinine (mg/dL)	1.80 (0.70–4.64)	0.22		
Preoperative hemoglobin (g/dL)	0.86 (0.72–1.03)	0.10		
Preoperative C-reactive protein (mg/L)	0.86 (0.65–1.23)	0.49		
Target vessel stenosis (%)				
<70	1		1	
≥70	0.40 (0.19–0.86)	0.02	0.42 (0.20–0.91)	0.03
Emergency	0.04 (0.00–11.18)	0.27		
Cardiopulmonary bypass time (min)	1.00 (0.98–1.01)	0.61		
Proximal anastomosis				
Aorta (direct)	1		1	
T-graft group	3.02 (1.39–6.58)	0.005	2.34 (1.01–5.19)	0.04
Distal area				
Left anterior descending artery	1			
Left circumflex artery	0.86 (0.38–1.94)	0.71		
Right coronary artery	1.19 (0.470–3.00)	0.72		
Sequential radial artery	0.26 (0.036–1.93)	0.19		

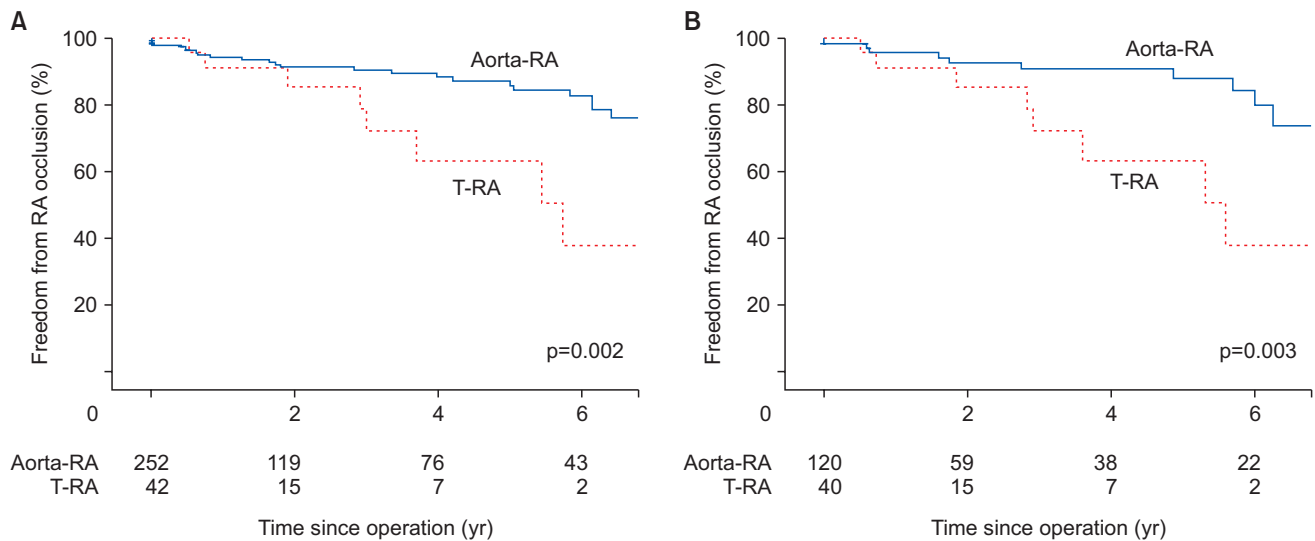CI, confidence interval; HR, hazard ratio.

Fig. 2. (A) Freedom from RA occlusion in the aorta-RA anastomosis group and T-RA anastomosis group in the unmatched cohort. (B) Results for the matched cohort. RA, radial artery.

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Table 5. Risk factors for overall mortality in unmatched patients

Variable	Univariable		Multivariable	
	HR (95% CI)	p-value	HR (95% CI)	p-value
Age (yr)	1.04 (1.01–1.08)	0.02		
Female	1.02 (0.56–1.85)	0.95		
Preoperative ejection fraction (%)	0.96 (0.95–0.98)	<0.001	0.97 (0.95–0.99)	0.002
Hypertension	0.72 (0.41–1.27)	0.26		
Diabetes mellitus	0.75 (0.41–1.37)	0.34		
Dyslipidemia	0.69 (0.31–1.53)	0.36		
Current smoker	0.96 (0.47–1.96)	0.92		
Chronic kidney disease	1.16 (0.63–2.13)	0.64		
Cerebrovascular accident	1.28 (0.46–3.56)	0.64		
Preoperative creatinine (mg/dL)	2.56 (1.11–5.92)	0.03		
Preoperative hemoglobin (g/dL)	0.76 (0.66–0.87)	<0.001	0.77 (0.67–0.89)	<0.001
Preoperative C-reactive protein (mg/L)	1.30 (1.16–1.46)	<0.001	1.20 (1.06–1.36)	0.01
Target vessel stenosis (%)				
<70	1		1	
≥70	3.68 (0.894–15.16)	0.07	3.12 (0.76–12.91)	0.12
Emergency operation	0.91 (0.28–2.92)	0.87		
Cardiopulmonary bypass time (min)	1.01 (1.00–1.01)	0.03		
Proximal anastomosis				
Aorta (direct)	1			
T-graft group	1.73 (0.88–3.40)	0.11		
Distal area				
Left anterior descending artery	1			
Left circumflex artery	1.51 (0.67–3.42)	0.33		
Right coronary artery	1.67 (0.64–4.39)	0.30		
Sequential radial artery	1.96 (0.95–4.05)	0.07		
RA patency	0.76 (0.27–2.15)	0.60		

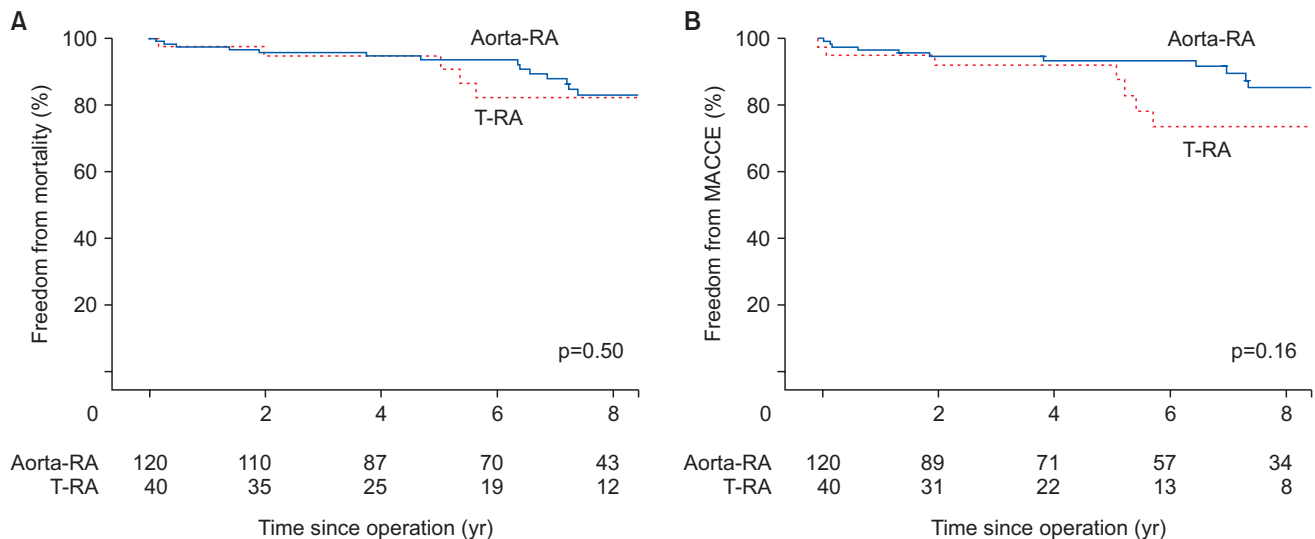CI, confidence interval; HR, hazard ratio.

Fig. 3. (A) Freedom from mortality. (B) Freedom from MACCE in the aorta-RA anastomosis group and T-RA anastomosis group in the matched cohort. MACCE, major adverse cardiac and cerebrovascular event; RA, radial artery.

Table 6. Risk factors for major adverse cardiac and cerebrovascular event in unmatched patients

Variable	Univariable		Multivariable	
	HR (95% CI)	p-value	HR (95% CI)	p-value
Age (yr)	1.03 (1.01–1.07)	0.02		
Female	1.04 (0.59–1.83)	0.89		
Preoperative ejection fraction (%)	0.97 (0.95–0.98)	<0.001	0.97 (0.95–0.99)	0.001
Hypertension	0.66 (0.39–1.12)	0.12		
Diabetes mellitus	0.90 (0.52–1.57)	0.72		
Dyslipidemia	0.59 (0.27–1.29)	0.19		
Current smoker	0.83 (0.40–1.69)	0.60		
Chronic kidney disease	1.38 (0.76–2.50)	0.29		
Cerebrovascular accident	1.13 (0.45–2.84)	0.79		
Preoperative creatinine (mg/dL)	2.55 (1.15–5.63)	0.02		
Preoperative hemoglobin (g/dL)	0.76 (0.67–0.86)	<0.001	0.76 (0.67–0.87)	<0.001
Preoperative C-reactive protein (mg/L)	1.27 (1.14–1.43)	<0.001	1.16 (1.03–1.32)	0.02
Target vessel stenosis (%)				
<70	1			
≥70	2.68 (0.84–8.56)	0.10		
Emergency operation	0.79 (0.25–2.53)	0.69		
Cardiopulmonary bypass time (min)	1.01 (0.10–1.01)	0.08		
Proximal anastomosis				
Aorta (direct)	1			
T-graft group	1.84 (0.99–3.44)	0.06		
Distal area				
Left anterior descending artery	1			
Left circumflex artery	1.49 (0.69–3.21)	0.31		
Right coronary artery	1.62 (0.65–4.03)	0.30		
Radial artery sequential	2.20 (1.13–4.26)	0.02		

CI, confidence interval; HR, hazard ratio.

Table 7. Analysis of direct aorta-RA configuration–related outcomes in the propensity-matched cohort

Outcomes	No. of events (%)	OR (95% CI)	p-value
RA occlusion			
Aorta-RA anastomosis[a]	12 (10.0)	1.00	
T-RA anastomosis	9 (22.5)	3.58 (1.46–8.77)	0.005
Overall mortality			
Aorta-RA anastomosis	14 (11.7)	1.00	
T-RA anastomosis	7 (17.0)	1.63 (0.65–4.07)	0.30
MACCE			
Aorta-RA anastomosis	12 (10.0)	1.00	
T-RA anastomosis	9 (22.5)	2.35 (0.98–5.60)	0.07

CI, confidence interval; MACCE, major adverse cardiac and cerebrovascular event; OR, odds ratio; RA, radial artery.
[a]The total number of patients in the aorta-RA anastomosis group was n=120, and that of the T-RA anastomosis group was n=40.

Outcomes in the propensity score-matched cohort

T-RA anastomosis configuration was identified as a significant risk factor for RA occlusion (HR, 3.58; 95% CI, 1.46–8.77; p=0.005). However, similar to the unmatched data, there was no statistically significant correlation with overall mortality (HR, 1.63; 95% CI, 0.65–4.07; p=0.30) or MACCE (HR, 2.35; 95% CI, 0.98–5.60; p=0.07) (Table 7).

Discussion

Our study indicated that the aorta-RA anastomosis configuration showed superior patency compared to the T-RA anastomosis configuration. However, this had no statistical significance for overall mortality or MACCE. The risk factors for RA occlusion consisted of target vessel stenosis and proximal anastomosis configuration. Preoperative ejection

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fraction and preoperative hemoglobin levels were significantly associated with mortality and MACCE.

Several previous studies regarding RA proximal configuration and patency reported no significant association. Kim et al. [10] demonstrated that the proximal anastomosis configuration was not significant if the degree of stenosis and distal territory of the target vessel are considered in the off-pump coronary artery bypass (OPCAB) group. In other studies, the proximal anastomosis configuration was found to be unrelated to patency [11-14]. They recommended T-RA anastomosis to minimize aortic manipulation, as well as using a longer length of graft to increase its usefulness. Kim et al. [10] analyzed a comparatively small group of patients who had undergone OPCAB. The study of Lemma et al. [11] also had limitations because the rate of patients who received patency evaluation after surgery was low (aorta-coronary group, 12%; Y graft group, 25.6%). The results may differ because of these factors.

Jung et al. [18] reported that the aorta-direct group showed better early and late patency rates than did the T-graft group. Those findings align with our results.

The reasons for these conflicting findings are unclear. There are conflicting theories in relation to the underlying physiology. When aorta-RA anastomosis is performed, intimal hyperplasia may be induced because the intima of the RA receives greater stress than the wall receives in the native position of the RA [17]. However, other studies have considered this to be an advantage in overcoming competing forces [14].

Regarding CVA risk, which is one of the biggest drawbacks of aorta-RA anastomosis, there were no statistically significant differences in the above studies, or in ours [10,12].

This study showed that the degree of target vessel stenosis was related to RA patency. This finding has already been demonstrated in other studies [15,16]; however, we confirmed that the configuration of RA graft was not related to mortality or MACCE. In other words, occlusion of the RA graft did not affect the risk of mortality and MACCE. A reason for this may be the limited clinical significance of the second graft. The preoperative ejection fraction and preoperative hemoglobin were identified as meaningful factors for both long-term outcomes. Preoperative ejection fraction is a well-known risk factor in cardiac surgery, and is used as a factor in the EuroSCORE [21]. The preoperative hemoglobin level is an indicator of the patient's condition before surgery and is predicted to act as a risk factor for long-term outcomes in relation to age and renal function [22,23].

This study has several limitations. First, the data were collected from a single institution. Therefore, the number of patients was relatively small. Additionally, this was a retrospective and non-randomized study. To overcome this limitation, we implemented propensity score matching. Nevertheless, confounding factors could not be ruled out. Second, the time of occlusion was assumed to be the date of postoperative cardiac CT or coronary angiography, although that date is unlikely to reflect the actual date of occlusion development. Third, although some patients did not properly receive CT or coronary angiography evaluation to ascertain patency because of kidney function deterioration or because they were lost to follow-up, the number of such patients was relatively small (10.4% out of 328). Therefore, the results were not significantly affected. Finally, the T-RA anastomosis group in our study seemed heterogeneous, including T-configurations from 2 different inflows (SVG and LIMA), which could have been a potential source of bias.

In conclusion, aorta-RA anastomosis showed a superior patency rate compared to T-RA anastomosis. More than 70% target vessel stenosis was associated with favorable patency. The RA proximal configuration was unrelated to mortality or MACCE. Future studies may be necessary to ascertain the relationship between the RA proximal anastomosis configuration and RA patency.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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Supplementary materials

Supplementary materials can be found via https://doi.org/10.5090/jcs.20.082. **Supplementary Table 1**. Patient characteristics of the propensity score-matched cohort.

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