Sequential Saphenous Vein Coronary Bypass Grafting

Does the Number of Distal Anastomoses per Single Vein Affect the Graft Patency?

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Summary

The enormous majority of previous reports focused on evaluating the safety and efficacy of sequential saphenous vein (SV) coronary bypass grafting; however, no reports to date have revealed concern regarding the impacts of the number of distal anastomoses of sequential SV grafting on graft patency after coronary artery bypass grafting (CABG). This single-center retrospective study aimed to evaluate the impacts of three versus two distal anastomoses per single SV conduit on SV graft patency after off-pump CABG, and to determine the independent risk factors for sequential SV graft failure.

From January 2011 to December 2014, 1320 eligible patients were assigned to either a triple group (three distal anastomoses of sequential SV grafting, $n = 758$) or a double group (two distal anastomoses of sequential SV grafting, $n = 562$). The primary endpoint was over a 2-year follow-up SV graft failure after off-pump CABG.

The triple and double group received a similar total patency rate of sequential SV conduits (86.5% versus 87.1%, $P = 0.757$). The number of distal anastomoses of sequential SV grafting (three versus two) was not a predictive factor for the follow-up graft failure of sequential SV conduits (HR = 0.91, 95% CI: 0.66-2.29, $P = 0.137$). Moreover, the two groups received a similar follow-up survival freedom from repeat revascularization ($\chi^2 = 1.881$, log-rank $P = 0.170$).

Three versus two distal anastomoses per single SV conduit received a similar SV graft patency. The number of distal anastomoses of sequential SV grafting was not an independent risk factor for graft failure.

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Key words: Coronary artery bypass grafting, Off-pump, Sequential saphenous vein grafting, Vein graft failure, Graft flow

Coronary artery bypass grafting surgery (CABG) provides symptomatic relief and increases the long-term survival in patients with coronary artery disease. The success of this surgery is majorly attributed to complete revascularization and graft patency.¹⁻⁵ Since its inception, several modifications have been proposed to improve the graft patency, including the choice of conduits,⁶⁻⁸ target coronaries selection,^{9,10} and the application of sequential grafting.^{11,12} Sequential grafting is a surgical technique, where more than one distal anastomosis is constructed per single conduit, thus resulting in two or more distal anastomoses per single proximal anastomosis. The strategy of sequential grafting of saphenous vein (SV) has been accepted by a majority of cardiac surgeons.¹¹⁻¹³ With the development of coronary surgery, an increasing number of patients who suffered from coronary artery disease with diffuse coronary disease or who received repeat CABG with limited available conduits pre-

ferred surgical revascularization. Accordingly, the use of sequential SV grafting was likely to increase.

The enormous majority of previous reports focused on evaluating the safety and efficacy of sequential SV grafting;¹¹⁻¹³ however, no reports to date have revealed concerns regarding the impacts of the number of distal anastomoses of sequential SV grafting on the patency rate of sequential SV conduits following CABG. Did the number of distal anastomoses of sequential SV grafting affect the graft patency of sequential SV conduits? Moreover, the majority of previous studies reported the impacts of sequential SV grafting on the angiographic and clinical outcomes following conventional CABG.¹¹⁻¹³ Off-pump CABG accounted for about 60% of all CABG procedures in Asian countries, and for over 70% in China according to the report of Chinese CABG registration study.¹⁴ In comparison with the conventional CABG, off-pump CABG may have negative impacts on the anastomotic

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quality, with negative consequences for graft patency and clinical outcomes; however, few studies focused on evaluating the impacts of sequential SV grafting on SV graft patency and clinical outcomes following isolated off-pump CABG.

In the present study, 1320 eligible patients in our medical center were reviewed and followed-up, to provide a present-day assessment of the impacts of three versus two distal anastomoses per single SV conduit on over 2-year follow-up patency rate of sequential SV conduits after off-pump CABG surgery, and to determine whether the number of distal anastomoses of sequential SV grafting was independently associated with the graft failure of sequential SV conduits.

Methods

Study population: Consecutive patients with double- or triple-vessel disease, who received first-time, isolated off-pump CABG in our medical center from January 2010 to December 2014, were identified. Only patients who received separate grafting of an *in situ* left internal mammary artery to the left anterior descending artery with sequential grafting of a single SV to the other coronary territories were included in this study. In our medical center, the number of distal anastomoses per single SV conduit was ≤ 3 ; alternatively, additional venous or arterial conduits grafting were conducted at one time. Cases undergoing multiple arterial grafts or with more than one venous conduit or with only one distal anastomosis per single SV conduit were excluded to minimize the surgical variability. Patients aged above 80 years or those with concomitant malignant tumor were excluded due to limited anticipated life expectancy. Furthermore, patients with hyperthyroidism, iodine contrast medium allergy, atrial fibrillation, and renal insufficiency may not be suitable candidates for non-invasive coronary computed tomographic (CT) angiography examination, and thus were not included in the final analysis.

Study protocol: This study protocol was approved by the ethics committee of Zhongshan Hospital Fudan University and was consistent with the Declaration of Helsinki (Trial registration: Current Controlled Trials ChiCTR-RRC-17013170). According to the number of distal anastomoses of sequential SV grafting, all included patients were assigned to a triple group (patients who received three distal anastomoses per single SV conduit) or a double group (patients who received two distal anastomoses per single SV conduit).

The primary endpoint was over a 2-year follow-up patency rate of sequential SV conduits following CABG determined by a noninvasive coronary CT angiography. Patency or failure of sequential SV conduits was determined by coronary CT angiography with a 64-slice, dual-source CT (iCT 64, Philips Healthcare, Amsterdam, Netherlands). The images were analyzed in off-line workstations (median effective irradiation of 7.5 mSv, interquartile range 3.76 mSv). A sequential SV conduit was divided into three or two SV segments according to the number of distal anastomoses. SV segments were evaluated for failure ($\geq 50\%$ lumen diameter reduction, and/or

reducing caliber of distal anastomosis $\geq 50\%$ of the grafted coronary artery). Total patency rate of the sequential SV conduits = (total number of distal anastomoses or SV segments - the number of occlusive anastomoses or failure SV segments)/total number of distal anastomoses or SV segments $\times 100\%$.

The secondary endpoints included follow-up clinical outcomes and in-hospital adverse events. The follow-up clinical outcomes were all-cause mortality and repeat revascularization. All-cause mortality rather than cardiac-cause mortality was chosen because it is the most robust and unbiased index, which exempted us from misinterpreting the cause of death with the subjective and often inaccurate medical records. Repeat revascularization was defined as a second percutaneous coronary intervention or redo CABG surgery to deal with the graft failure or new high-grade native coronary artery stenosis. In-hospital adverse events included surgical mortality¹⁵⁾ and major post-operative morbidity¹⁶⁾ (including myocardial infarction associated with CABG, prolonged ventilation (more than 48 hours), reoperation before discharge from the hospital, stroke, and deep sternal wound infection).

Surgical techniques and postoperative medications:

Surgery aims to achieve complete revascularization, which is defined as bypass grafting to all epicardial coronary arteries ≥ 1.5 mm with a diameter reduction $\geq 50\%$ in at least one angiographic view.¹⁷⁾ Great saphenous veins were harvested with an open technique. Detailed off-pump CABG procedure was referred to the related literature.¹⁸⁾ Surgeons were at liberty to choose from sequential or separate SV grafting for each case. Factors influencing the surgeons' preference for sequential or separate SV grafting may have included the length and size of available SV conduits; the desire to limit manipulation of the proximal aorta and to increase manipulation of the SV conduits; and preconceptions regarding the safety and efficacy of sequential SV grafting. Sequential anastomoses of the SV to target the coronary arteries were conducted in a side-to-side manner for the intermediate anastomoses and an end-to-side manner for the last anastomosis with a double-armed 7-0 polypropylene suture and a continuous suturing technique. The quality of anastomosis was assessed after grafting with a transit-time flow probe (Medistim Butterfly Flowmeter, Oslo, Norway) during the operation. When the probe was applied to the sequential SV segments before the first distal anastomosis without clamping the SV segments that followed, the obtained value was considered as the "trunk flow" of sequential SV conduits.

Subcutaneous injection of low molecular weight heparin within 6 hours following off-pump CABG was routinely performed, except for the patients undergoing reoperation for bleeding. Statin medication, aspirin, and clopidogrel were routinely prescribed to all the included patients starting from the postoperative day 1. Statin medication and aspirin were continued indefinitely, whereas clopidogrel was discontinued after 1 year.

Statistical analysis: Perioperative data were obtained from our institutional database and reviewed using a standard data collection form. Follow-up data were obtained by telephone and clinic visit. Data collection was performed by the trained staff (two people). The trained staff,

Figure 1. Flow chart for the selection of study population.

however, was unaware regarding the purpose of the study.

Normally distributed continuous variables were expressed as the mean $\pm$ standard deviation and were compared between groups using the Student's *t*-test. Abnormally distributed continuous variables were expressed as median and were compared between groups with the Wilcoxon rank sum test. Categorical variables were expressed as frequency distributions and single percentages and were compared between groups using χ^2 test and Fisher's exact test, when appropriate. Estimations for risk of graft failure of sequential SV conduits were calculated using the Cox regression analysis (baseline and surgical data, intraoperative SV graft flow, and grouping as the dependent variables, and SV graft failure or SV graft patency as the independent variables). The impacts of grouping as an independent factor on the in-hospital adverse events were evaluated by multivariable logistic regression analysis with a backward method. Follow-up survival analysis was conducted by the Kaplan-Meier method with the log-rank test for group comparisons, and estimations for the risk of follow-up survival freedom from repeat revascularization were conducted by using Cox regression analysis. A value of two-sided $P < 0.05$ was considered as statistically significant. Statistical analysis was performed with SPSS statistical package version 17.0 (SPSS Inc., Chicago, IL, USA).

Results

Study population: From January 2010 to December 2014, 1936 consecutive patients with double-vessel or triple-vessel disease who received first-time, isolated off-pump CABG, accounting for 68.1% of all CABG cases in our medical center, were identified. As presented in Figure 1, 1320 eligible patients were finally analyzed. Among these, 758 patients who received three distal anastomoses per single SV conduit were allotted to the triple group, and the remaining 562 patients who received two distal anastomoses per single SV conduit were included in the double group.

Baseline characteristics are presented in Table I. No significant differences between the two groups were found in the demographics. The two groups revealed similar proportions of concomitant diseases. No significant differences between the two groups were found in the cardiac status before surgery, except for the ratio of triple-vessel disease (95.4% for the triple group versus 54.8% for the double group, $P < 0.001$).

The mean number of distal anastomoses was 4 in the triple group and 3 in the double group, respectively. Table II lists the grafts and target coronary arteries. The triple group compared to the double group, received significantly higher proportions of revascularization of the di-

Table I. Baseline Characteristics and Surgical Data

	Triple group (n = 758)	Double group (n = 562)	P value
Demographics			
Age (years)	64.9 ± 7.4	65.2 ± 6.8	0.451
Older age (> 65 years)	371 (48.9%)	284 (50.5%)	0.568
Female	83 (10.9%)	66 (11.7%)	0.652
Obesity	116 (15.3%)	83 (14.8%)	0.788
Smoking history	320 (42.2%)	228 (40.6%)	0.548
Concomitant diseases			
Diabetes mellitus	281 (37.1%)	221 (39.3%)	0.405
Hypertension	400 (52.7%)	308 (54.8%)	0.464
Hyperlipidemia	167 (22.0%)	118 (21.0%)	0.651
COPD	83 (10.9%)	58 (10.3%)	0.714
Prior CVA	59 (7.8%)	40 (7.1%)	0.650
Cardiac status			
Congestive heart failure	160 (21.1%)	113 (20.1%)	0.657
LVD	107 (14.1%)	86 (15.3%)	0.364
Recent MI	225 (29.7%)	157 (27.9%)	0.489
Atrial fibrillation	12 (1.6%)	14 (2.5%)	0.240
Enlarged left ventricle	23 (3.0%)	25 (4.4%)	0.175
History of PCI	215 (28.4%)	141 (25.1%)	0.185
Coronary artery lesion			
2-vessel	35 (4.6%)	254 (45.2%)	< 0.001
3-vessel	723 (95.4%)	308 (54.8%)	
Left main trunk disease	235 (31.0%)	156 (27.8%)	0.202
Surgical data			
Urgent operation	31 (4.1%)	26 (4.6%)	0.635
Number of distal anastomoses	4.0	3.0	
Use of skeletonized IMA	379 (50.0%)	265 (47.2%)	0.306
IABP support	45 (5.9%)	36 (6.4%)	0.726
Sequential SV graft flow (mL/min)			
Trunk flow	45.2 ± 13.6	42.4 ± 12.3	< 0.001
Last sequential SV segment flow	14.7 ± 4.4	15.1 ± 4.2	0.096

Triple group, patients who received three distal anastomoses performed with a single SV conduit; double group, patients who received two distal anastomoses performed with a single SV conduit. COPD indicates chronic obstructive pulmonary disease; CVA, cerebrovascular accident; LVD, left ventricular dysfunction; MI, myocardial infarction; PCI, percutaneous cardiac intervention; IMA, internal mammary artery; SV, saphenous vein; and IABP, intra-aortic balloon pump. Obesity is defined as body mass index of more than 30 kg/m²; Congestive heart failure, NYHA class III and IV; Recent MI, evidence of myocardial infarction within the last 30 days before surgery; LVD, left ventricular ejection fraction of less than 40%; Enlarged left ventricle, left ventricular endo-diastolic diameter of more than 65 mm; Trunk flow, sequential SV graft flow prior to the first anastomosis; and Last sequential SV segment flow, sequential SV graft flow prior to the last anastomosis.

Table II. List of Grafts and Target Coronary Arteries

	Triple group (n = 758)	Double group (n = 562)
LIMA	<i>In situ</i> LIMA-LAD (758)	<i>In situ</i> LIMA-LAD (562)
SVG	D, OM, and PDA (561)	D and PDA (261)
	D, OM, and RCA (84)	OM and PDA (196)
	OM ₁ , OM ₂ , and PDA (45)	D and OM (56)
	D, OM ₁ , and OM ₂ (24)	D and RCA (26)
	OM ₁ , OM ₂ , and RCA (21)	D and AM (12)
	D, PDA, and AM (11)	OM and RCA (8)
	OM, PDA, and AM (8)	OM and AM (3)
	D, OM, and AM (4)	

Number enclosed in brackets indicates number of patients. LIMA indicates left internal mammary artery; LAD, left anterior descending artery; D, diagonal artery; OM, obtuse marginal artery; PDA, posterior descending artery; RCA, right coronary artery; and AM, acute marginal artery.

agonal artery, circumflex territory, and right coronary territory (90.2% versus 63.2%, $P < 0.001$; 98.5% versus 46.8%, $P < 0.001$; 96.8% versus 90.0%, $P < 0.001$, respectively). As presented in Table I, no significant differences between the two groups were found in the proportions of urgent operation, use of skeletonized internal mammary artery, and application of intra-aortic balloon pump. Notably, the triple group compared to the double group revealed a significantly higher trunk flow (45.2 ± 13.6 mL/minutes versus 42.4 ± 12.3 mL/minutes, $P < 0.001$) but a similar last sequential SV segment flow (14.7 ± 4.4 mL/minutes versus 15.1 ± 4.2 mL/minutes, $P = 0.096$). Measured pulsatility index of all sequential SV segments was lower than 5.

SV graft patency: A total of 1175 patients (672 patients in the triple group and 503 patients in the double group)

Table III. Graft Patency of Sequential SV Conduits

	Triple group	Double group	P value
1st sequential segments failure	4.5% (30/672)	7.4% (37/503)	0.034
Middle sequential segments failure	3.7% (25/672)		
Last sequential segments failure	9.7% (65/672)	9.5% (48/503)	0.940
All sequential segments failure	3.3% (22/672)	4.0% (20/503)	0.412
Complete occlusion of SV grafts	1.0% (7/672)	1.6% (8/503)	0.407
Total SV graft patency	86.5% (581/672)	87.1% (438/503)	0.757

SV indicates saphenous vein.

Table IV. Clinical Outcomes After CABG Surgery

	Triple group	Double group	P value
In-hospital outcomes			
Number of patients	758	562	
Surgical mortality	8 (1.1%)	7 (1.2%)	0.747
Myocardial infarction	13 (1.7%)	11 (2.0%)	0.745
Prolonged ventilation	22 (2.9%)	18 (3.2%)	0.753
Stroke	14 (1.8%)	8 (1.4%)	0.552
Deep sternal wound infection	6 (0.8%)	5 (0.9%)	0.846
Reoperation before discharge	12 (1.6%)	7 (1.2%)	0.611
Follow-up outcomes			
Number of patients	681	510	
All-cause mortality	29 (4.3%)	24 (4.7%)	0.711
Cardiac-cause mortality	7 (1.0%)	7 (1.4%)	0.585
Repeat revascularization	10 (1.5%)	11 (2.2%)	0.372

were examined more than once for coronary CT angiography per person during the follow-up period of 24-78 months (46.6 ± 12.1 months). Table III lists the detailed coronary CT angiographic results. The two groups received a similar over 2-year total SV graft patency (86.5% for the triple group versus 87.1% for the double group, $P = 0.757$). The complete occlusion of SV conduits was observed in 1.3% of patients who received coronary CT angiography examination (7 patients in the triple group versus 8 in the double group, $P = 0.407$). Note that the graft failure rate of the first sequential SV segments in the triple group was significantly lower than that in the double group (4.5% versus 7.4%, $P = 0.034$).

Risk factors for graft failure of sequential SV conduits: Graft failure of sequential SV conduits was observed in 156 patients (91 patients in the triple group and 65 patients in the double group) during the follow-up period of over 2 years, which was 13.3%. Data including the demographic characteristics, concomitant diseases, preoperative cardiac status, intraoperative SV graft flow (trunk flow and the last sequential SV segment flow), and grouping (the triple group versus the double group) as the dependent variables were entered into the Cox regression analysis (graft failure of sequential SV conduits or not as the independent variable). Results indicated that grouping (the triple group versus the double group) was not a significant variable related to graft failure of sequential SV conduits (HR = 0.91, 95% CI: 0.66-2.29, $P = 0.137$), whereas the last sequential SV segment flow was a significant variable related to graft failure of sequential SV conduits (HR = 0.85, 95% CI: 0.61-0.94, $P = 0.024$). In particular, pa-

tients with graft failure of sequential SV conduits compared to patients with graft patency of sequential SV conduits revealed a significantly lower last sequential SV segment flow (12.1 ± 3.7 mL/minute versus 15.3 ± 4.3 mL/minute, $P < 0.001$).

Clinical outcomes: As presented in Table IV, no significant differences between the two groups were found during the incidences of in-hospital adverse events. The impacts of grouping on the in-hospital adverse events after adjusting for the potential confounders (older age, gender, obesity, smoking history, concomitant disease, and preoperative cardiac status) are presented in Table V. In multivariable logistic regression analysis, grouping (the triple group versus the double group) was not found to be an independent predictor of the in-hospital adverse events.

A total of 1191 patients, accounting for 90.2% of all selected patients, were followed-up for more than 2 years. Fifty-three patients died, and all-cause mortality was 4.5%. A total of 21 patients (1.8%) received repeat revascularization during the follow-up. Only one patient in the double group received repeat on-pump CABG due to LIMA graft occlusion, and the remaining 20 patients preferred percutaneous coronary intervention instead of repeat CABG surgery due to SV graft failure (16 patients: 9 in the triple group and 7 in the double group) or disease progression that were not grafted at the time of the initial surgery (4 patients: 1 in the triple group and 3 in the double group). As presented in Figure 2, Kaplan-Meier curves revealed that the two groups received a similar follow-up survival freedom from repeat revascularization ($\chi^2 = 1.881$, log-rank $P = 0.170$). Moreover, the Cox regression analysis revealed that grouping (the triple group versus the double group) was not an independent factor for the follow-up survival freedom from repeat revascularization (HR = 1.212, 95% CI: 0.836-2.518, $P = 0.132$).

Discussion

The core finding of the present study emphasized that the two groups received a similar graft patency of sequential SV conduits; and the number of distal anastomoses of sequential SV grafting was not independently associated with the graft failure of the sequential SV conduits. In this study, three instead of two distal anastomoses of sequential SV grafting revealed a slightly lower over 2-year total SV graft patency after off-pump CABG, although this difference was devoid of statistical significance (86.5% versus 87.1%, $P = 0.757$). The Cox regression analysis revealed that grouping (the triple group ver-

sus the double group) was not a significant variable related to graft failure of sequential SV conduits. Hence, these evidences suggested that the three distal anastomoses of sequential SV grafting received a similar SV graft patency as the two distal anastomoses of sequential SV grafting.

Graft flow during an operation is reportedly useful for detecting technical failure and predicting graft occlusion. Early venous graft failure is caused by technical failure, thrombosis, and intimal hyperplasia. This is the initial process of atherosclerosis, which forms the main cause of late graft failure.¹⁹⁾ In this cohort, the patients with graft failure of sequential SV conduits revealed a significantly

lower last sequential SV segment flow as compared to the patients with graft patency of sequential SV conduits. Furthermore, the Cox regression analysis revealed that the last sequential SV segment flow was a significant variable related to graft failure of sequential SV conduits. Therefore, these evidences suggested that the last sequential SV segment flow instead of the number of distal anastomoses of sequential SV grafting played a crucial role in predicting the follow-up graft patency of the sequential SV conduits. Notably, the graft failure rate of the first sequential SV segments in the triple group was significantly lower than that in the double group. The reason for this difference may be related to a higher trunk flow of sequential SV conduits in the case of three distal anastomoses of sequential SV grafting.

The implications of these results are as follows. The appropriate number of distal anastomoses per single SV conduit may be determined by the last sequential SV segment flow in the case of planning sequential SV grafting. For the three targets, which seem to have sufficient flow demand, three distal anastomoses per single SV grafting may be a suitable choice in the case of “satisfactory” last sequential SV segment flow (greater than the acceptable threshold value). Alternatively, two distal anastomoses per single SV conduit or only one distal anastomosis per single SV conduit with additional SV or arterial conduits grafting was recommended. Further studies with multicenter, large sample, and long-term follow-up are required to

Table V. Risk-Adjusted Effects of the Triple Group Versus the Double Group on In-Hospital Adverse Events

	OR	95% CI	P value
Surgical mortality	0.876	0.305-2.346	0.796
Myocardial infarction	0.894	0.389-1.966	0.836
Prolonged ventilation	0.933	0.480-1.701	0.749
Stroke	1.231	0.543-3.128	0.666
Deep sternal wound infection	0.905	0.270-2.927	0.985
Re-operation before discharge	1.215	0.499-3.260	0.649

Adjustment for potential confounders included age, gender, obesity, smoking history, concomitant disease, preoperative cardiac status, and the number of grafts. OR indicates odds ratio; and CI, confidence interval.

Figure 2. Cumulative survival free from repeat revascularization. The triple group, patients who received three distal anastomoses per single SV conduit; the double group, patients who received two distal anastomoses per single SV conduit.

determine the acceptable threshold value of the last sequential SV segment flow. Moreover, the present study revealed that the patency rate of the distal end in sequential SV grafting was significantly lower than that of the proximal portion. We would suggest that sequential SV grafting with a proximal for an important target and the distal for a less important target may be rationalized as it may be reasonable to sacrifice a bypass of the distal end to assure patency to the important target. Not only should the run-off of the target, but also the importance be considered.²⁰⁾

In addition, this study reported that patients in the two groups received similar follow-up and in-hospital clinical outcomes. Under conditions of similar baseline data, grouping was neither an independent predictor of the in-hospital adverse events nor an independent factor for the follow-up survival freedom from repeat revascularization. These evidences suggested that the impacts on the clinical outcomes revealed no difference between the two groups. Therefore, both the three and two distal anastomoses of sequential SV grafting received similar clinical outcomes. Notably, despite receiving distinct number of grafts (4.0 versus 3.0), the two groups revealed similar clinical outcomes. The lack of clinical benefit despite more extensive revascularization in the triple group may be due to a plateau effect seen with greater than three bypass grafts.²¹⁾ Furthermore, shorter duration of follow-up may be another factor for the lack of clinical benefit despite more extensive revascularization in the triple group.

This study had some potential limitations. First, it was a single-center retrospective study. The unobserved confounds and selection biases between the two groups cannot be eliminated. Second, noninvasive coronary CT angiography was used to determine the SV graft patency, which may be less accurate than the invasive coronary angiography; however, it is widely preferred by patients who schedule for an examination of graft patency. In recent decades, the noninvasive imaging techniques have allowed direct visualization of atherosclerotic disease into coronary arteries and arterial and venous grafts, and have revealed an excellent correlation with invasive angiography.²²⁾ Third, angiographic data were limited, and we could not ascertain the inner diameter of SV, the degree of target coronary arteries stenosis, target coronary arteries for each grafting strategy or postoperative graft patency. Fourth, the duration of follow-up in this study was relatively short, and the long-term outcomes need longer observation to confirm this result. Despite these limitations, to the best of our knowledge, this report is the first to examine the impacts of the number of distal anastomoses of sequential SV grafting on SV graft patency in a large, well-defined, contemporary off-pump CABG population.

Conclusion

This single-center retrospective study demonstrated that both the three and two distal anastomoses of sequential SV grafting received a similar SV graft patency after isolated off-pump CABG; and the number of distal anastomoses of sequential SV grafting was not an independent risk factor for graft failure of sequential SV conduits.

Disclosures

Conflicts of interest: None.

References

1. Serruys PW, Unger F, Sousa JE, *et al.* Comparison of coronary-artery bypass surgery and stenting for the treatment of multivessel disease. *N Engl J Med* 2001; 344: 1117-24.
2. Bypass Angioplasty Revascularization Investigation (BARI) Investigators. Comparison of coronary bypass surgery with angioplasty in patients with multivessel disease. *N Engl J Med* 1996; 335: 217-25.
3. Fitzgibbon GM, Kafka HP, Leach AJ, Keon WJ, Hooper GD, Burton JR. Coronary bypass graft fate and patient outcome: angiographic follow-up of 5,065 grafts related to survival and reoperation in 1,388 patients during 25 years. *J Am Coll Cardiol* 1996; 28: 616-26.
4. Lattouf OM, Thourani VH, Kilgo PD, *et al.* Influence of on-pump versus off-pump techniques and completeness of revascularization on long-term survival after coronary artery bypass. *Ann Thorac Surg* 2008; 86: 797-805.
5. Synnergren MJ, Ekroth R, Odén A, Rexius H, Wiklund L. Incomplete revascularization reduces survival benefit of coronary artery bypass grafting: role of off-pump surgery. *J Thorac Cardiovasc Surg* 2008; 136: 29-36.
6. Cameron A, Davis KB, Green G, Schaff HV. Coronary bypass surgery with internal-thoracic-artery grafts--effects on survival over a 15-year period. *N Engl J Med* 1996; 334: 216-9.
7. 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.
8. Nicolini F, Vezzani A, Romano G, *et al.* Coronary artery bypass grafting with arterial conduits in the elderly. *Int Heart J* 2017; 58: 647-53.
9. Cosgrove DM, Loop FD, Saunders CL, Lytle BW, Kramer JR. Should coronary arteries with less than fifty percent stenosis be bypassed? *J Thorac Cardiovasc Surg* 1981; 82: 520-30.
10. Desai ND, Naylor CD, Kiss A, *et al.* Impact of patient and target-vessel characteristics on arterial and venous bypass graft patency: insight from a randomized trial. *Circulation* 2007; 115: 684-91.
11. Ouzounian M, Hassan A, Yip AM, *et al.* The impact of sequential grafting on clinical outcomes following coronary artery bypass grafting. *Eur J Cardiothorac Surg* 2010; 38: 579-84.
12. Gao C, Wang M, Wang G, *et al.* Patency of sequential and individual saphenous vein grafts after off-pump coronary artery bypass grafting. *J Card Surg* 2010; 25: 633-7.
13. Li J, Liu Y, Zheng J, *et al.* The patency of sequential and individual vein coronary bypass grafts: a systematic review. *Ann Thorac Surg* 2011; 92: 1292-8.
14. Rao C, Zhang H, Gao H, *et al.* The Chinese cardiac surgery registry: design and data audit. *Ann Thorac Surg* 2016; 101: 1514-20.
15. Ji Q, Lai H, Sun Y, *et al.* Impact of presurgical mild acute respiratory distress syndrome on surgical mortality after surgical repair of acute type A aortic dissection. *Int Heart J* 2017; 58: 739-45.
16. Ji Q, Shi Y, Xia L, *et al.* Revascularization of left coronary system using a skeletonized left internal mammary artery-sequential versus separate grafting. *Circ J* 2017; 82: 102-9.
17. Ong AT, Serruys PW. Complete revascularization: coronary artery bypass graft surgery versus percutaneous coronary intervention. *Circulation* 2006; 114: 249-55.
18. Xia L, Ji Q, Song K, *et al.* Early clinical outcomes of on-pump beating-heart versus off-pump technique for surgical revascularization in patients with severe left ventricular dysfunction: the experience of a single center. *J Cardiothorac Surg* 2017; 12: 11.
19. Sabik JF. Understanding saphenous vein graft patency. *Circula-*

- tion 2011; 124: 273-5.
20. Takazawa A, Nakajima H, Iguchi A, *et al.* Impacts of intraoperative flow on graft patency of sequential and individual saphenous vein grafts. *Innovations (Phila)* 2015; 10: 85-9.
 21. Bell MR, Gersh BJ, Schaff HV, *et al.* Effect of completeness of revascularization on long-term outcome of patients with three-vessel disease undergoing coronary artery bypass surgery. A report from the coronary artery surgery study (CASS) registry. *Circulation* 1992; 86: 446-57.
 22. Weustink AC, Nieman K, Pugliese F, *et al.* Diagnostic accuracy of computed tomography angiography in patients after bypass grafting: Comparison with invasive coronary angiography. *JACC Cardiovasc Imaging* 2009; 2: 816-24.