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Twenty-Year Follow-up: Multiple Arterial Grafting Is Associated with Better Outcomes for Coronary Artery Bypass Grafting Patients

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Abstract

Objectives: The optimal conduits for coronary artery bypass grafting (CABG) remain controversial in multivessel coronary artery disease. Some studies have shown that multiple arterial conduits offer better long-term survival. We sought to analyze the long term outcomes of arterial graft during CABG in our institute.

Methods: Retrospective cohort analyses of all patients undergoing primary isolated CABG in King Chulalongkorn Memorial Hospital, Bangkok, Thailand, from January 1997 – December 2001. We stratified patients into three groups including patients with multiple arterial graft (MAG) versus single arterial graft (SAG) versus non-arterial graft (NAG). The primary outcome was survival rate. The secondary outcome was time to first event of a composite of death, MI, stroke, and repeat revascularization (major adverse cardiac and cerebrovascular events, MACCE).

Results: Four hundred sixty four patients underwent isolated CABG during our study period; 67 patients (14.4%) in multiple arterial graft group (MAG), 293 patients (63.1%) in single arterial graft group (SAG) and 104 patients (22.5%) in non-arterial graft group (NAG). Mean and maximum follow-up was 12.5 and 24.5 years, respectively. Median age of population is 63 years (IQR 56-69) with 60 years in MAG, 63 years in SAG and 66 years in NAG (P < 0.001).Most common second arterial conduit is radial artery grafting, accounting for 76 patients (16.4%). Other baseline characteristics are not different between groups. In-hospital mortality was 0% for MAG vs 1.7% in SAG and 5.8% in NAG (P = 0.04). On the other hand, 20-year survival of MAG, SAG and NAG is 52.9%, 44.3% and 23.7%, respectively. At 20 years, incidences of MACCE, survival, repeat revascularization, and myocardial infarction were inferior in multiple arterial groups. The risk factors associated with death were non-arterial graft, age more than 60 years, low BMI, diabetic mellitus, renal dysfunction, pre-operative IABP, cardiopulmonary bypass time more than 75 minutes and postoperative atrial fibrillation.

Conclusion: CABG with multiple arterial grafts was associated with better clinical outcomes compare with single and non-arterial graft at 20-year follow-up.

Introduction

For a long time, coronary artery disease has been a leading cause of death worldwide which kills more than 3, 00,000 people per year. Up until now, there are many scientific evidences proving that coronary artery revascularization improves survival and reduces incidence of major adverse cardiac events (MACEs) [1]. There are two principal methods of coronary revascularization including coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI). It has been shown in many studies that CABG offers advantages over PCI in patients with complex coronary anatomy especially in diabetic patients [2,3]. CABG needs conduits to bypass the stenotic coronary lesion which were shown in many studies that multiple arterial conduits offer better long-term outcome compared with single arterial and venous conduits [4-7]. However, these studies investigated mainly in western population and very little of them follow-up more than ten years. Our study took place in a tertiary care hospital in Thailand with twenty-year follow-up aiming to compare survival and incidence of major adverse cardiac or cerebrovascular events (MACCEs) in patients who underwent coronary artery bypass grafting with different types of conduits application.

Methods

The study population was derived from all consecutive patients who underwent primary isolated CABG in King Chulalongkorn Memorial Hospital, Bangkok, Thailand from January 1, 1997 to December 31, 2001. Inpatient, outpatients, emergency department and operative records were retrospectively reviewed. Patients who lost follow-up were telephone follow-up by investigators. Inclusion criteria were patients who underwent primary isolated CABG with any graft configuration. Exclusion criteria were patients who underwent redo CABG, non-isolated CABG (combined with valve or aortic operation) and incomplete data of grafting strategy. The primary outcome of this study is twenty-year survival. The secondary outcome is incidence of major adverse cardiac and cerebrovascular events (MACCEs). The study was approved by the Institutional Review Board of the faculty of Medicine, Chulalongkorn University, Bangkok, Thailand in compliance with the international guidelines for human research protection as Declaration of Helsinki, The Belmont Report, CIOMS Guideline and international Conference on Harmonization in Good Clinical Practice (ICH-GCP).

Preoperative demographic data including sex, age, BMI, preoperative hematocrit, angina grading (Canadian Cardiovascular Society, CCS), Dyspnea grading (New York Heart Association, NYHA), history of congestive heart failure (CHF) and myocardial infarction (MI), underlying disease, coronary lesion and left ventricular function were collected. Intraoperative data including grafting strategy, urgency of operation, mechanical support necessity, cardioplegia delivery strategy, cardiopulmonary bypass (CPB) and

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aortic cross-clamp time were collected. Postoperative course data including complications, length of stay (LOS) and ICU stay were collected. Follow-up data including all-cause death, incidence of MACCEs were collected. In patients who underwent re-coronary angiography due to any indication, the patency of grafts was also reviewed.

There were 464 patients who met the inclusion criteria. Their preoperative demographic data were demonstrated in Table 1. Patients were classified as multiple arterial graft group (MAG) if they were grafted with two or more arterial conduits, single arterial graft group (SAG) if they were grafted with one arterial conduit and non-arterial graft group (NAG) if no arterial conduit was used.

Stata version 15.1 (Stata Corp., College Station, Texas), was used for analysis. Continuous variables are expressed as median (interquartile range: IQR) and percentage for categorical variables. Differences in continuous and categorical variables between three groups were assessed using a Kruskal Wallis test and Chi-square test or fisher exact test, respectively. The survival rate and incidence of MACCEs were calculated by Kaplan Meier and log rank test for comparison between groups. The Cox regression was used to determine the factors associated with mortality and incidence of MACCEs. Multivariate models were developed by adjusting for covariates with $p < 0.1$ in univariate models to determine risk factors associated with mortality and using stepwise backward LR for incidence of MACCEs. All P-values reported are two-sided. Statistical significance was defined as $P < 0.05$.

Results

There were 67 (14.4%) patients in MAG, 293 (63.1%) patients in SAG and 104 (22.5%) patients in NAG with male predominant in each group but not statistically significant between groups (P = 0.29). The median age of population is 63 years (IQR 56-69) with 60 years (IQR 54-65) in MAG, 63 years (IQR 56-68) in SAG and 66 years (IQR 59-73) in NAG (P < 0.001). Most patients (381 in 464, 82.1%) have trouble with angina symptoms predominantly class II CCS (82.9%). 198 patients (42.7%) have a history of hospitalization with congestive heart failure or acute coronary syndrome. Most patients have triple vessel disease (360 in 464, 77.6%). Median preoperative LVEF is 58% (IQR 40-70) (Table 1).

Table 1: Characteristics of patient by grafting strategy.

Variable	Total (N=464)	Multiple arterial graft (N=67)	Single arterial graft (N=293)	Non-arterial graft (N=104)	P-value
Male, n (%)	298 (64.2)	47 (70.2)	190 (64.9)	61 (58.7)	0.29
Age (years), median (IQR)	63 (56 - 69)	60 (54 - 65)	63 (56 - 68)	66 (59 - 73)	<0.001
BW, median (IQR)	62.6 (55.3 - 70)	63.2 (57 - 70.1)	63.4 (55.9 - 70)	60.4 (53 - 67.5)	0.12
BMI, median (IQR)	24.1 (22 - 26.6)	24.5 (22 - 26)	24.1 (22.2 - 26.7)	23.8 (21.3 - 26.7)	0.67
Hct, median (IQR)	34.1 (30.1 - 38)	35.3 (33 - 38.5)	34.1 (30 - 38.1)	33.5 (30 - 36.7)	0.08
Hx					
Angina (class), n (%)					0.27
0 - 1	83 (17.9)	13 (19.4)	51 (17.4)	19 (18.3)	
2	316 (68.1)	47 (70.2)	206 (70.3)	63 (60.6)	
3	64 (13.8)	7 (10.5)	35 (12)	22 (21.2)	
4	1 (0.2)	0 (0)	1 (0.3)	0 (0)	
Dyspnea (class), n (%)					0.32
0 - 1	277 (59.7)	35 (52.2)	173 (59)	69 (66.4)	
2	115 (24.8)	22 (32.8)	75 (25.6)	18 (17.3)	
3	71 (15.3)	10 (14.9)	44 (15)	17 (16.4)	
4	1 (0.2)	0 (0)	1 (0.3)	0 (0)	
Hx of CHF, n (%)	50 (10.8)	6 (9)	30 (10.2)	14 (13.5)	0.58
Hx of MI, n (%)	148 (31.9)	22 (32.8)	86 (29.4)	40 (38.5)	0.23
U/D, n (%)					
DM	195 (42)	25 (37.3)	132 (45.1)	38 (36.5)	0.22
HT	271 (58.4)	40 (59.7)	166 (56.7)	65 (62.5)	0.57
DLP	195 (42)	33 (49.3)	123 (42)	39 (37.5)	0.32
Renal dysfunction	47 (10.1)	2 (3)	31 (10.6)	14 (13.5)	0.06
Current smoker	132 (28.5)	19 (28.4)	86 (29.4)	27 (26)	0.81
Old CVA	27 (5.8)	1 (1.5)	20 (6.8)	6 (5.8)	0.26
COPD	5 (1.1)	0 (0)	4 (1.4)	1 (1)	0.61
PAD	9 (1.9)	1 (1.5)	8 (2.7)	0 (0)	0.25
Coronary lesion, n (%)					
SVD	16 (3.5)	2 (3)	12 (4.1)	2 (1.9)	0.66
DVD	78 (16.8)	10 (14.9)	43 (14.7)	25 (24)	0.08
TVD	360 (77.6)	54 (80.6)	231 (78.8)	75 (72.1)	0.30
LM	90 (19.4)	11 (16.4)	58 (19.8)	21 (20.2)	0.79
LVEF (%, IQR)	58 (40 - 70)	60 (43 - 72)	59 (41 - 70)	51 (36 - 67)	0.08

Compare proportion (%) using chi-square and Compare continuous data using Kruskal wallis test.

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Table 2 Intraoperative variable by grafting strategy

Variable	Total (N=464)	Multiple arterial graft (N=67)	Single arterial graft (N=293)	Non arterial graft (N=104)	p-value
Conduit					
IMA					<0.001
- 0	117 (25.2)	0 (0)	13 (4.4)	104 (100)	
- 1	342 (73.7)	62 (92.5)	280 (95.6)	0 (0)	
- 2	5 (1.1)	5 (7.5)	0 (0)	0 (0)	
SVG					<0.001
- 0	13 (2.8)	9 (13.4)	4 (1.4)	0 (0)	
- 1	59 (12.5)	26 (38.8)	30 (10.2)	3 (2.9)	
- 2	177 (38.2)	25 (37.3)	129 (44)	23 (22.1)	
- 3	182 (39.2)	5 (7.5)	116 (39.6)	61 (58.7)	
- 4	30 (6.5)	2 (3)	12 (4.1)	16 (15.4)	
- 5	3 (0.7)	0 (0)	2 (0.7)	1 (0.9)	
RA					<0.001
- 0	388 (83.6)	1 (1.5)	284 (96.9)	104 (100)	
- 1	71 (15.3)	61 (91)	9 (3.1)	0 (0)	
- 2	5 (1.1)	5 (7.5)	0 (0)	0 (0)	
Endarterectomy	6 (1.3)	0 (0)	3 (1)	3 (2.9)	0.26
Elective surgery	446 (96.1)	65 (97)	285 (97.3)	96 (92.3)	0.10
Emergency surgery	18 (3.9)	2 (3)	8 (2.7)	8 (7.7)	0.10
IABP Pre op	26 (5.6)	3 (4.5)	14 (4.8)	9 (8.7)	0.32
Cardioplegia					
Antegrade	212 (45.7)	13 (19.4)	131 (44.7)	68 (65.4)	<0.001
Antegrade +Retrograde	236 (50.9)	52 (77.6)	152 (51.9)	32 (30.8)	<0.001
CPB (time (min)	102 (85 - 125)	125 (95 - 155)	102.5 (85 - 121)	91.5 (78 - 109)	<0.001
Clamp time	59 (48 - 73.5)	75 (60 - 101)	60 (50 - 73)	48 (41 - 58)	<0.001
ONBEAT	6 (1.3)	2 (3)	2 (0.7)	2 (1.9)	0.11

Intraoperative data were listed in Table 2. In MAG, left internal thoracic artery (LITA) grafted to left anterior descending artery (LAD) was used in all 67 patients with 5 patients (1.1%) underwent bilateral internal thoracic artery (BITA) grafting. Radial artery (RA) was used in 76 patients (16.4%). Bilateral radial artery was used in 4 patients with 1 patient underwent bilateral radial artery grafted to three coronary targets (left radial artery grafted to two obtuse marginal arteries sequentially and right radial artery grafted to posterior descending artery). No gastroepiploic artery was used in any patient. In SAG, 280 patients (95.6%) underwent LITA grafted to LAD. Coronary endarterectomy was done in 6 patients (1.3%) with 3 patients in SAG and 3 patients in NAG. There were 18 patients (3.9%) who underwent emergency operation and 26 patients (5.6%) needed a preoperative intra-aortic balloon pump (IABP). Median CPB time was 102 minutes (IQR 85 - 125) with 125 minutes (IQR 95 - 155) in MAG, 102.5 minutes (IQR 85 - 121) in SAG and 91.5 minutes (IQR 78 - 109) in NAG ($P < 0.001$). Median aortic cross-clamp time was 59 minutes (IQR 48 - 73.5) with 75 minutes (IQR 60 - 101) in MAG, 60 minutes (IQR 50 - 73) in SAG and 48 minutes (IQR 41 - 58) in NAG ($P < 0.001$).

Postoperative myocardial infarction occurred in one patient (0.2%) in SAG, the coronary angiography showed stenosis at anastomosis of LITA to LAD and the patient underwent anastomosis revision successfully. CHF and low cardiac output syndrome (LCOS) occurred in 23 patients (5%). Postoperative atrial fibrillation (AF) occurred in 74 patients (16%). There was renal dysfunction in 67 patients (14.4%) which 89% recovered before discharge. In-hospital mortality occurred in 11 patients (2.4%) (Table 3).

During 20-year follow-up, mortality occurred in 237 patients (51.1%) with 27 patients (40.3%) in MAG, 144 patients (49.2%) in SAG and 66 patients (63.5%) in NAG ($P < 0.007$) (Table 4).

In MAG, survival at 5,10, 15, 20 years were 91%, 73.8%, 64.5% and 52.9%, respectively. Survival at 5, 10, 15, 20 years were 84.8%, 70.4%, 55.3% and 44.3%, respectively in SAG. In NAG, survival at 5, 10, 15, 20 years were 71.9%, 49.4%, 42.1% and 23.7%, respectively (Table 5, Figure 1).

In univariate analysis, risk factors associated with death were non-arterial graft (HR = 2.26; 95% CI 1.44 - 3.54, $P < 0.001$), age ≥ 60 years (HR = 2.15; 95% CI 1.6 - 2.88, $P < 0.001$), BMI < 18.5 kg/m^2 (HR = 4.72; 95% CI 2.31 - 9.66, $P < 0.001$), Hematocrit < 30% (HR = 2.28; 95% CI 1.71 - 3.02, $P < 0.001$), history of MI (HR = 1.38; 95% CI 1.05 - 1.79, $P = 0.02$), diabetes mellitus (HR = 1.66; 95% CI 1.28 - 2.14, $P < 0.001$), renal dysfunction (HR = 2.2; 95% CI 1.53 - 3.17, $P < 0.001$), old CVA (HR = 1.74; 95% CI 1.06 - 2.85, $P = 0.03$), COPD (HR = 5.02; 95% CI 1.85 - 13.57, $P < 0.001$), PAD (HR = 2.72; 95% CI 1.39 - 5.3, $P < 0.001$), LVEF < 50% (HR = 1.53; 95% CI 1.17 - 2, $P = 0.002$), preoperative IABP (HR = 2.17; 95% CI 1.39 - 3.4, $P < 0.001$), CPB time > 75 min (HR = 1.71; 95% CI 1.13 - 2.57, $P = 0.01$), postoperative MI (HR = 37.9; 95% CI 4.93 - 291.47, $P < 0.001$), postoperative CHF (HR = 3.79; 95% CI 2.01 - 7.14, $P < 0.001$), postoperative AF (HR = 1.96; 95% CI 1.44 - 2.68, $P < 0.001$), postoperative renal dysfunction (HR = 2.14; 95% CI 1.55 - 2.95, $P < 0.001$). Route of cardioplegia

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Table 3: Postoperative variable by grafting strategy.

Variable	Total	Multiple arterial graft (N=67)	Single arterial graft (N=293)	Non arterial graft (N=104)	p-value
Post-operation					
MI	1 (0.2)	0 (0)	1 (0.3)	0 (0)	0.75
CHF	11 (2.4)	1 (1.5)	5 (1.7)	5 (4.8)	0.20
LCOS	12 (2.6)	0 (0)	8 (2.7)	4 (3.9)	0.29
AF	74 (16)	17 (25.4)	44 (15)	13 (12.5)	0.07
Dialysis	7 (1.5)	0 (0)	4 (1.4)	3 (2.9)	0.39
Recovered	60 (12.9)	11 (16.4)	40 (13.7)	9 (8.7)	0.28
Stroke	3 (0.7)	1 (1.5)	2 (0.7)	0 (0)	0.49
Re-op stop bleed	8 (1.7)	3 (4.5)	4 (1.4)	1 (1)	0.51
ICU stay (days)	2 (1 - 3)	2 (2 - 7)	2 (1 - 3)	2 (1 - 2)	<0.001
LOS (days)	9 (7 - 12)	7 (2 - 11)	9 (7 - 12)	10 (7 - 13)	0.001
In-hospital death	11 (2.4)	0 (0)	5 (1.7)	6 (5.8)	0.04

Compare proportion (%) using chi-square and Compare continuous data using Kruskal wallis test.

Table 4: Follow-up variable by grafting strategy

Variable	Total	Multiple arterial graft (N=67)	Single arterial graft (N=293)	Non arterial graft (N=104)	p- value
All Death	237 (51.1)	27 (40.3)	144 (49.2)	66 (63.5)	0.007
Angina	70 (15.1)	10 (14.9)	49 (16.7)	11 (10.6)	0.32
Dyspnea(NYHA class)					0.23
- 1	328 (70.7)	53 (79.1)	206 (70.3)	69 (66.4)	
- 2	104 (22.4)	13 (19.4)	65 (22.2)	26 (25)	
- 3	31 (6.7)	1 (1.5)	22 (7.5)	8 (7.7)	
- 4	1 (0.2)	0 (0)	0 (0)	1 (1)	
No CAG	41 (23.2)	5 (18.5)	21 (19.4)	15 (35.7)	
Graft patency					
Arterial graft					<0.001
- 0	45 (25.4)	1 (3.7)	18 (16.7)	0 (0)	
- 1	77 (43.5)	7 (25.9)	69 (63.9)	0 (0)	
- 2	13 (7.3)	13 (48.2)	0 (0)	0 (0)	
- 3	1 (0.6)	1 (3.7)	0 (0)	0 (0)	
Vein graft					0.01
- 0	17 (12.4)	5 (22.7)	11 (12.6)	1 (3.6)	
- 1	48 (35)	13 (59.1)	28 (32.2)	7 (25)	
- 2	38 (27.7)	4 (18.2)	26 (29.9)	8 (28.6)	
- 3	28 (20.4)	0 (0)	19 (21.8)	9 (32.1)	
- 4	5 (3.7)	0 (0)	2 (2.3)	3 (10.7)	
- 5	1 (0.7)	0 (0)	1 (1.2)	0 (0)	

*Graft patency (arterial graft and vein graft) grading 0 - 5 wasnumber of grafts that were not stenosis in patients who underwent re-coronary angiography.

Table 5: Long-term survival by grafting strategy.

Year after operation	Total			Multiple arterial graft (MAG)			Single arterial graft (SAG)			Non arterial graft (NAG)		
	%	95%CI		%	95%CI		%	95%CI		%	95%CI	
5	82.8	79.1	86.0	91.0	81.2	95.9	84.8	80.2	88.5	71.9	62.1	79.5
10	66.3	61.6	70.5	73.8	61.2	82.8	70.4	64.6	75.4	49.4	38.9	59.0
15	53.7	48.6	58.5	64.5	51.0	75.1	55.3	48.8	61.3	42.1	31.6	52.3
20	41.2	35.9	46.3	52.9	38.5	65.4	44.3	37.7	50.7	23.7	14.3	34.3

including antegrade or antergrade combined with retrograde were not statistically significant risk factors associated with death. After multivariate analysis, the risk factors associated with death were non-arterial graft (HR = 2.56; 95% CI 1.57 - 4.16, P < 0.001), age $\geq$ 60 years (HR = 1.9; 95% CI 1.38 - 2.63, P < 0.001), BMI < 18.5 kg/m^2 (HR = 3.06; 95% CI 1.39 - 6.74, P = 0.01), diabetes mellitus (HR = 1.56; 95% CI 1.18 - 2.06, P = 0.002), renal dysfunction (HR = 1.56; 95% CI 1.02 - 2.38, P = 0.04), preoperative IABP (HR = 2.05; 95% CI 1.26 - 3.32, P < 0.001), CPB time (HR = 1.61; 95% CI 1.05 - 2.47, P = 0.03), postoperative AF (HR = 1.7; 95% CI 1.19 - 2.43, P = 0.003), postoperative renal dysfunction (HR = 1.84; 95% CI 1.29 - 2.61, P = 0.001) (Table 6).

The cumulative incidence of MACCEs in MAG at 5, 10, 15, 20 years were 9.4%, 29%, 47.6% and 57.2%, respectively. In SAG, the cumulative incidence of MACCEs at 5, 10, 15, 20 years were 17.9%,

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Table 6: Risk factors associated with death.

Group	Univariable		Multivariable	
	HR (95%CI)	P-value	aHR (95%CI)	P-value
Multiple arterial graft	1		1	
Single arterial graft	1.31 (0.87-1.97)	0.20	1.31 (0.85-2.01)	0.22
Non-arterial graft	2.26 (1.44-3.54)	<0.001	2.56 (1.57-4.16)	<0.001
Female	1.24 (0.95-1.62)	0.11		
Age ≥ 60 years	2.15 (1.6-2.88)	<0.001	1.9 (1.38-2.63)	<0.001
BMI < 18.5	4.72 (2.31-9.66)	<0.001	3.06 (1.39-6.74)	0.01
Smoking	0.84 (0.63-1.12)	0.24		
Hct < 30%	2.28 (1.71-3.02)	<0.001	1.27 (0.91-1.76)	0.16
Hx of CHF	1.07 (0.7-1.65)	0.74		
Hx of MI	1.38 (1.05-1.79)	0.02	1.13 (0.84-1.53)	0.42
Underlying				
DM	1.66 (1.28-2.14)	<0.001	1.56 (1.18-2.06)	0.002
HT	1.11 (0.85-1.43)	0.45		
DLP	0.98 (0.76-1.27)	0.90		
Renal dysfunction	2.2 (1.53-3.17)	<0.001	1.56 (1.02-2.38)	0.04
Old CVA	1.74 (1.06-2.85)	0.03	0.97 (0.54-1.74)	0.91
COPD	5.02 (1.85-13.57)	<0.001	2.86 (0.88-9.31)	0.08
PAD	2.72 (1.39-5.3)	<0.001	1.92 (0.94-3.92)	0.07
Coronary lesion				
SVD	0.7 (0.36-1.37)	0.30		
DVD	0.96 (0.68-1.35)	0.81		
TVD	1.2 (0.88-1.63)	0.25		
LM	0.93 (0.67-1.29)	0.66		
LVEF < 50%	1.53 (1.17-2)	0.002	1.11 (0.82-1.5)	0.50
Urgency of operation				
Elective surgery	1			
Emergency surgery	1.49 (0.79-2.8)	0.22		
Preop IABP	2.17 (1.39-3.4)	<0.001	2.05 (1.26-3.32)	<0.001
Intraoperative				
Antegrade cardioplegia	0.93 (0.72-1.21)	0.59		
Antegrade + Retrograde cardioplegia	1.19 (0.92-1.53)	0.19		
CPB time > 75 min	1.71 (1.13-2.57)	0.01	1.61 (1.05-2.47)	0.03
Clamp time> 60 min	1.08 (0.84-1.41)	0.54		
ONBEAT	2.8 (0.89-8.81)	0.08	1.35 (0.38-4.79)	0.64
Postoperative				
MI	37.9 (4.93-291.47)	<0.001	1.56 (0.11-21.69)	0.74
CHF	3.79 (2.01-7.14)	<0.001	1.17 (0.51-2.64)	0.71
LCOS	1.96 (0.87-4.42)	0.10		
AF	1.96 (1.44-2.68)	<0.001	1.7 (1.19-2.43)	0.003
Dialysis	6.08 (2.69-13.74)	<0.001	2.2 (0.75-6.42)	0.15
Recovered	2.14 (1.55-2.95)	<0.001	1.84 (1.29-2.61)	0.001
Stroke	1.71 (0.42-6.91)	0.45		
Re-op stop bleed	1.03 (0.42-2.49)	0.95		

HR = hazard ratios, aHR = adjusted hazard ratios. Univariate and Multivariate model were used Cox regression, multivariate models were developed by adjusting for covariates with p<0.1 in univariate models.

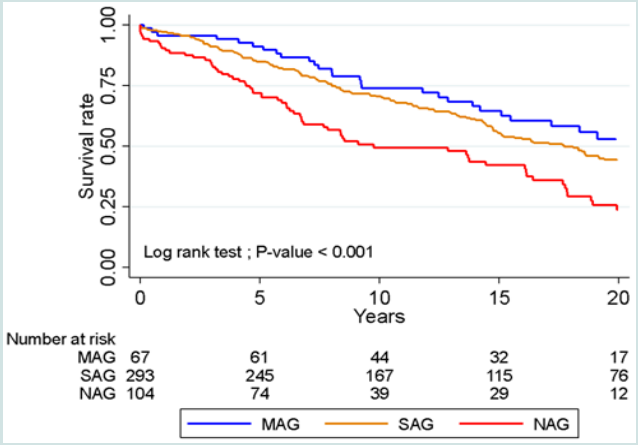

Figure 1: Long-term survival by grafting strategy.

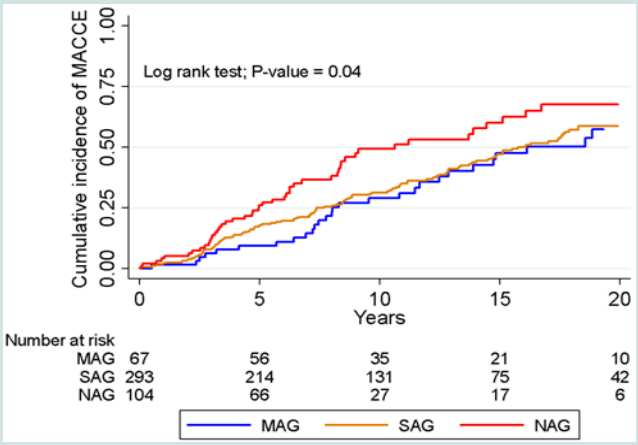

Figure 2: Cumulative incidence of MACCEs by grafting strategy

31.3%, 47.1%, 58.7% and in NAG were 26%, 49.3%, 60% and 67.6%, respectively (Table 7, Figure 2).

Discussion

Since the invention of CABG in the 1960s, a number of studies have proved us that CABG improves survival of patients with coronary artery disease. Most contemporary evidence showed a trend toward better results with arterial conduit, especially total arterial revascularization. An internal thoracic artery, especially left, grafted to LAD has been a standard configuration to improve patient's survival. Also, radial artery is a recommended conduit utilized to graft the second most important non-LAD coronary target [8]. The guideline of coronary artery bypass grafting also recommend multiple arterial grafting especially in younger patients as the conduit

Table 7: Cumulative incidence of MACCEs by grafting strategy.

Year after operation	Total			Multiple arterial graft			Single arterial graft			Non arterial graft		
	%	95%CI		%	95%CI		%	95%CI		%	95%CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
5	18.4	15.0	22.4	9.4	4.3	19.7	17.9	13.9	23.0	26.0	18.2	36.3
10	34.7	30.1	39.8	29.0	19.1	42.6	31.3	25.8	37.6	49.3	38.6	61.1
15	49.9	44.5	55.7	47.6	34.7	62.5	47.1	40.4	54.4	60.0	48.1	72.3
20	60.4	54.5	66.4	57.2	42.8	72.6	58.7	51.3	66.3	67.6	54.9	79.7

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patency is compatible with patients' life expectancy [9]. Despite having more benefit in straightforward cases, arterial conduits have some drawbacks in emergency situation and in patients with poor LV function since arterial spasm may hinder the conduits from providing immediate coronary revascularization. Also, there are some challenges when grafting arterial conduits on non-critical stenotic coronary targets because of the competitive flow [10]. On the other hand, saphenous vein grafts have low propensity for spasm and can provide immediate coronary flow. Besides, in patients with severe co morbidities and limited life expectancy, saphenous vein grafts offer a simpler procedure and a shorter operative time. Most of this knowledge derived from western centers where most of the study population is Caucasian. Whether the smaller stature and smaller vessels, especially arteries, of Asians impede the benefit of arterial graft over vein graft is one of the motivations of our study [11]. The purpose of this study was to determine the long-term outcome up to twenty years of multiple arterial grafting, single arterial grafting and non-arterial grafting.

In our study, median age of population is 63 years with male predominate, the most common coronary pathology is triple vessels disease and mean LVEF is around 50% which is comparable to other studies [4,7,12,13]. The survival at 5, 10, 15 and 20 years of MAG in our data is 91%, 73.8%, 64.5% and 52.9%, in SAG is 84.8%, 70.4%, 55.3%, 44.3% and in NAG is 71.9%, 49.4%, 42.1% and 23.7%, respectively. These may be implied that the more arterial graft, the more survival benefit. Nevertheless, we did not compare multiple arterial grafts in subgroup of two, three or more arterial graft due to small number of patients in each subgroup. The cumulative incidence of MACCEs at 5, 10, 15 and 20 years in our cohort is 9.4%, 29%, 47.6% and 57.2% in MAG, 17.9%, 31.3%, 47.1% and 58.7% in SAG and 26%, 49.3%, 60% and 67.6% in NAG, respectively. These may suggest the benefit of second arterial graft, mostly radial artery, in the first 10 years after operation and the benefit of LITA grafted to LAD that last up to 20 years after operation. Rocha and colleagues reported the survival at 5, 8 years of MAG to be 91.3%, 83.6% and 89.3%, 80.3% in SAG which are comparable with our study [5]. They also reported the cumulative incidence of MACCEs at 5, 8 years to be 17.5%, 27.4% in MAG and 21.4%, 32.5% in SAG which is more than ours. The reason of fewer incidences of MACCEs at 5 years of our study may be due to less BMI and less incidence of PAD in our population. The survival and MACCEs in the report of Parasca and colleagues are also on par with Rocha's [12]. Although there was a trend toward more satisfactory survival outcome of MAG than SAG in our study, this was not account to statistically significant as shown in both univariate and multivariate analysis. This may be due to not large enough sample size or not long enough follow-up as Kaplan-Meier graphs of MAG and SAG are slowly apart from each other as the time goes by. In our study, most of the second arterial conduit is radial artery. When compared to data from RAPCO trial (RAPCO-SV) which reported 10 years survival of RA group to be 72.6% [14], 10 years survival of MAG in our study is 73.8% corresponding to that of RAPCO. The objection is that the mean age of population in RAPCO-SV is 72.6 years which is older than ours. On the other hand, in RAPCO-RITA (mean age of RA arm is 59.2 years), the 10 years survival of RA arm is reported to be 90.9% which is better than ours. These may be explained by much fewer diabetic patients (11% vs 37.3%) in RA arm in RAPCO-RITA and smaller RA size of Asians as our concern in the first place [11]. In both univariate and multivariate analysis of our study also showed diabetes to be risk factor of death. From our intraoperative data, combined antegrade and retrograde cardioplegia delivery technique was used more in MAG than SAG and NAG. We believed that these were due to surgeon preference. CPB time and aortic cross clamp time were also longest in MAG. All of these factors did not account for death or MACCEs in multivariate analysis except CPB time which was a risk factor for death but not MACCEs.

There were some limitations of our study. First, it was a retrospective cross-sectional analysis which may be confounded by selection bias. Second, the study population was quite small when compared to the other previous cohort [4,5,12,13]. Third, the operative outcomes may be partly related to operative techniques which have been fine-tuned over time. Finally, the conduit selected for bypass may be biased by coronary target and patients' comorbidities such as patients with severe comorbidities, limited life expectancy and poor coronary target may be grafted by saphenous vein.

Conclusion

Multiple arterial grafting is associated with better twenty-year survival compared with single arterial grafting and non-arterial grafting. The cumulative incidence of MACCEs is also higher in patients who underwent CABG with single arterial grafting and non-arterial grafting.

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