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Individual Versus Sequential Saphenous Vein Grafts for on-Pump Coronary Artery Bypass Grafting – Does Smaller Coronaries in Indians Affect Graft Choice? – A Mid-Term Patency Comparison Study

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Abstract

Purpose: Although multiarterial grafting or bilateral mammary artery use is being increasingly emphasized for contemporary coronary artery bypass grafting (CABG) practice, saphenous vein graft (SVG) still accounts for 80% of all CABG conduits (Park et al., 2020) [1]. In India, both the individual and sequential saphenous grafting techniques are used arbitrarily, and there has not been a study that compares the mid-term patency of these two. This is specially relevant in view of smaller coronaries in Indians than the Caucasian counterparts. This study aims to compare the patency for on pump CABG's.

Methods: In the present study, 323 patients underwent either sequential (group A, N = 151 grafts, each graft having two anastomoses each) or individual (group B, N = 344 grafts) saphenous vein CABG, between February 2014 and June 2017. The SVG anastomoses were created on obtuse marginal (OM1/OM2) and posterior descending artery (PDA). The graft patency of the vein grafts as well as the left internal mammary artery were assessed by serial coronary angiograms.

Results: Results were evaluated at 6 months, 1, 2 and 3 years post operatively. Group A showed a higher graft patency at 3 years at 80.8%, and group B, 67.1% (P = 0.002). Also, anastomoses on sequential conduits had overall better patency rates at three years (77.2% vs 67.2%, P = 0.005). The groups showed similar results at one year post operatively.

Conclusions: Sequential bypass grafts were associated with superior mid-term patency compared with individual grafts. These findings suggest the more favourable results of sequential bypass grafting to be attributed to the enhanced flow haemodynamics.

Keywords: Coronary artery bypass grafting, Sequential grafting, Individual grafting, Coronary arteries, Saphenous vein grafting technique

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1. Introduction

Despite the introduction and popularisation of a variety of arterial grafts having supposedly superior long-term patency rates, saphenous vein grafts continue to be the backbone of daily coronary revascularisation practice [2]. There is an ample amount of controversy as to whether sequential or individual grafting should be performed in bypass grafting. Sequential grafting is a technique whereby more than one distal anastomosis is constructed per segment of conduit used, thus resulting in two or more distal anastomoses per single proximal anastomosis. The advocates of this technique describe the haemodynamic advantage of increased total graft flow through improved distal runoff and, by extension,

Table IA. Overall comparison of the patency of sequential and individual venous conduits at 6 months post operatively.

A. At 6 months post operatively			
Outcome	No. of individual SVG	No. of sequential SVG	No. of LIMA pedicled grafts
Patent	298	133	321
Partially patent	10	7	1
Occluded	36	11	1
Total	344	151	323

Overall patency (including partial patency) in case of individual grafts = 89.5%.

Overall patency (including partial patency) in case of sequential grafts = 92.7%.

Overall patency (including partial patency) in case of LIMA = 99.7%.

P value is 0.266, implies there is no significant difference between individual and sequential graft patency.

Table IB. Overall comparison of the patency of sequential and individual venous conduits at 1 year post operatively (data from 0 to 1 yr).

B. At 1 year post operatively (data from 0 to 1 yr)			
Outcome	No. of Individual SVG	No. of Sequential SVG	No. of LIMA pedicled grafts
Patent	241	112	315
Partially patent	24	19	3
Occluded	79	20	5
Total	344	151	323

Overall patency (including partial patency) in case of individual grafts = 77.03%.

Overall patency (including partial patency) in case of sequential grafts = 86.8%.

Overall patency (including partial patency) in case of LIMA = 98.5%.

P value is 0.013, implying that the sequential SVGs have superior patency than the individual ones ($P < 0.05$).

Abbreviations

CABG	coronary artery bypass grafting
SVG	saphenous venous grafting
OM	obtuse marginal
PDA	posterior descending artery
LM	left main
LCx	left circumflex
TIA	transient ischaemic attacks
COPD	chronic obstructive pulmonary disease
LIMA	left internal mammary artery
Cx	circumflex

increased graft patency rates [3,4]. Sequential grafting helps to minimise aortic manipulation and, in some cases, allows anastomoses to smaller coronary arteries [5–7]. Despite these purported advantages, the acceptance of sequential grafting

Table IC. Overall comparison of the patency of sequential and individual venous conduits at 2 years post operatively (data from 0 to 2 yrs).

C. At 2 years post operatively (data from 0 to 2 years)			
Outcome	No. Of individual SVG	No. Of sequential SVG	No. Of LIMA pedicled grafts
Patent	219	107	309
Partially patent	28	19	4
Occluded	97	25	10
Total	344	151	323

Overall patency (including partial patency) in case of individual grafts = 71.8%.

Overall patency (including partial patency) in case of sequential grafts = 83.4%.

Overall patency (including partial patency) in case of LIMA = 96.9%.

P value is 0.006, implying that the sequential SVGs have markedly superior patency than the individual ones ($P < 0.05$).

Table ID. Overall comparison of the patency of sequential and individual venous conduits at 3 years post operatively (data from 0 to 3 yrs).

D. At 3 years post operatively (data from 0 to 3 years)			
Outcome	No. of Individual SVG	No. of Sequential SVG	No. of LIMA pedicled grafts
Patent	197	100	298
Partially patent	34	22	6
Occluded	113	29	19
Total	344	151	323

Overall patency (including partial patency) in case of individual grafts = 67.1%.

Overall patency (including partial patency) in case of sequential grafts = 80.8%.

Overall patency (including partial patency) in case of LIMA = 94.1%.

P value is 0.002, implying that the sequential SVGs have markedly superior patency than the individual ones ($P < 0.05$).

Table IIAi. Patency rates for anastomoses on sequential conduits at 6 months post operatively.

II. Overall comparison of the patency of anastomoses on Cx and PDA systems between sequential and individual conduits

A. At 6 months post operatively

i. Patency rates for anastomoses on sequential conduits

Coronary artery system	Patent	Occluded	Total	Percentage of patency
Cx (OM ₁ /OM ₂)	138	13	151	91.4
PDA	137	14	151	90.7
Total	275	27	302	

Overall patency for anastomoses on sequential conduits = $275/302 \times 100 = 91.1\%$.

Table IIAii. Patency rates for anastomoses on individual conduits at 6 months post operatively.

ii. Patency rates for anastomoses on individual conduits

Coronary artery system	Patent	Occluded	Total	Percentage of patency
Cx (OM ₁ /OM ₂)	152	20	172	88.4
PDA	156	16	172	90.7
Total	308	36	344	

Overall patency for anastomoses on individual conduits = $308/344 \times 100 = 89.5\%$.

P value is 0.515, i.e., there is no significant difference between individual and sequential anastomoses.

Table IIBi. Patency rates for anastomoses on sequential conduits at 1 year post operatively.

B. At 1 year post operatively (data from 0 to 1 year)

i) Patency rates for anastomoses on sequential conduits

Coronary artery system	Patent	Occluded	Total	Percentage of patency
Cx (OM ₁ /OM ₂)	126	25	151	83.4
PDA	128	23	151	84.8
Total	254	48	302	

Overall patency for anastomoses on sequential conduits = $254/302 \times 100 = 84.1\%$.

Table IIBii. Patency rates for anastomoses on individual conduits at 1 year post operatively.

ii) Patency rates for anastomoses on individual conduits

Coronary artery system	Patent	Occluded	Total	Percentage of patency
Cx (OM ₁ /OM ₂)	129	43	172	75
PDA	136	36	172	79.1
Total	265	79	344	

Overall patency for anastomoses on individual conduits = $265/344 \times 100 = 77\%$.

P value is 0.024, implies there is significant difference between individual and sequential anastomoses.

Table IICi. Patency rates for anastomoses on sequential conduits at 2 year post operatively.

C. At 2 years post operatively (data from 0 to 2 years)

i) Patency rates for anastomoses on sequential conduits

Coronary artery system	Patent	Occluded	Total	Percentage of patency
Cx (OM ₁ /OM ₂)	122	29	151	80.8
PDA	125	26	151	82.8
Total	247	55	302	

Overall patency for anastomoses on sequential conduits = $247/302 \times 100 = 81.8\%$.

Table IICii. Patency rates for anastomoses on individual conduits at 2 years post operatively.

ii) Patency rates for anastomoses on individual conduits

Coronary artery system	Patent	Occluded	Total	Percentage of patency
Cx (OM ₁ /OM ₂)	117	55	172	68.0
PDA	130	42	172	75.6
Total	247	97	344	

Overall patency for anastomoses on individual conduits = $247/344 \times 100 = 71.8\%$.

P value is 0.0004, implies there is significant difference between individual and sequential anastomoses.

Table IIDi. Patency rates for anastomoses on sequential conduits at 3 years post operatively.

D. At 3 years post operatively (data from 0 to 3 years)

i) Patency rates for anastomoses on sequential conduits

Coronary artery system	Patent	Occluded	Total	Percentage of patency
Cx (OM ₁ /OM ₂)	115	36	151	76.2
PDA	118	33	151	78.1
Total	233	69	302	

Overall patency for anastomoses on sequential conduits = $233/302 \times 100 = 77.2\%$.

amongst surgeons as their default choice has been less than unanimous. This is due to the dependence of multiple grafts on a common inflow with the possibility of conduit block in the event of a proximal occlusion [8,9]. Conversely, in case of individual grafts, in case of individual graft occlusion, a large segment of the myocardium gets spared. (Table IA,B,C,D) (Table IIA,B,C,D, E,F,G,H) (Table IIIA,B,C,D).

1.1. In this study we have attempted to

1. Draw a comparison between the patency rates of the individual versus sequential conduits, documented 6 months, 1,2 and 3 years post coronary artery bypass surgery

Table IIDii. Patency rates for anastomoses on sequential conduits at 3 years post operatively.

ii) Patency rates for anastomoses on individual conduits				
Coronary artery system	Patent	Occluded	Total	Percentage of patency
Cx (OM ₁ /OM ₂)	105	67	172	61
PDA	126	46	172	73.3
Total	231	113	344	

Overall patency for anastomoses on individual conduits = $231/344 \times 100 = 67.2\%$.

P value is 0.005, i.e., there is significant difference between individual and sequential anastomoses.

Interpretation: The overall patency for sequential anastomoses was better than individual anastomoses, irrespective of the location of the anastomosis, on the 1st, 2nd and 3rd years of follow up.

Table IIIA. Overall comparison between the patency of anastomoses based on individual coronary artery systems (irrespective of type of anastomoses) at 6 months post operatively.

A) At 6 months post operatively				
Coronary artery system	Outcome at 6 months			P value
	Patent	Occluded	Patency rate (%)	
Cx (OM ₁ /OM ₂) system	290	33	89.78	0.691
PDA system	293	30	90.71	

Table IIIB. Overall comparison between the patency of anastomoses based on individual coronary artery systems at 1 year post operatively.

B) At 1 year post operatively				
Coronary artery system	Outcome at 1 year			P value
	Patent	Occluded	Patency rate (%)	
Cx (OM ₁ /OM ₂) system	255	68	78.95	0.373
PDA system	264	59	81.73	

Table IIIC. Overall comparison between the patency of anastomoses based on individual coronary artery systems at 2 years post operatively.

C) At 2 years post operatively				
Coronary artery system	Outcome at 2 years			P value
	Patent	Occluded	Patency rate (%)	
Cx (OM ₁ /OM ₂) system	239	84	73.99	0.138
PDA system	255	68	78.95	

2. Compare between the patency of anastomoses on individual and sequential saphenous vein grafts, at 6 months, 1,2 and 3 years post surgery
3. Compare between the patency of anastomoses based on individual coronary artery systems, at 6 months, 1,2 and 3 years post surgery

Table IIID. Overall comparison between the patency of anastomoses based on individual coronary artery systems at 3 years post operatively.

D) At 3 years post operatively				
Coronary artery system	Outcome at 3 years			P value
	Patent	Occluded	Patency rate (%)	
Cx (OM ₁ /OM ₂) system	220	103	68.11	0.036
PDA system	244	79	75.54	

Interpretation: Anastomosis on the PDA system is superior to that on the Cx system, irrespective of the type of anastomosis, according to the mid term data; but the same does not hold true prior to that. Further follow up is required to analyse long term patency rates.

We are hereby publishing the results of mid term patency with comparison of the patency rates. The aim is to continue this study till ten years of follow up, and compare the long term patency rates.

2. Materials and methods

A total of 323 patients were considered for this prospective study, all had ischaemic heart disease with triple vessel disease. The study was conducted in a single centre, Grant Medical College and Sir JJ Group of Hospitals, Mumbai, India. Total number of female patients were 57 and male patients were 266. Mean age was 62.25 ± 8.62 (Range 42–80) years. Vessel involvements involved the left anterior descending artery (LAD) with or without left main (LM) coronary artery involvement, left circumflex (LCx) in the form of obtuse marginal (OM₁/OM₂) involvement and posterior descending artery (PDA) involvement. Vessels in which LAD and any other one vessel was involved (double vessel), and those requiring more than three distal anastomoses, were excluded. Documented comorbidities were diabetes mellitus, hypertension, raised creatinine, previous history of transient ischaemic attacks (TIA), chronic obstructive pulmonary disease (COPD), raised liver enzymes. Those with disorders like a severe unresolved cerebrovascular accident (CVA), advanced malignancies, end stage kidney disease, and also concomitant other cardiac abnormalities like valve lesions, aortic root enlargement were excluded. Patients were divided into two randomised cohorts based on Simple Randomisation by a coin flipping technique; undergoing either i) sequential (for heads) or, ii) individual (for tails) saphenous vein coronary artery bypass grafting. No age or sex predilection or ejection fraction predilection was chosen. The patients were operated between February 2014 and June 2017. No patient had simultaneous inclusion of both types of conduits in them.

2.1. Operative technique

Totally 3 surgeons had operated. The bypass surgery was performed on pump at a temperature of 30 °C. Saphenous veins were harvested from the left lower limb by open technique, and in a few occasions, from the right lower limb as well. St. Thomas cardioplegia was used. After going on cardiopulmonary bypass, the heart was subjected to cardioplegic arrest and the distal anastomoses on OM1/OM2, PDA and LAD were performed. Pedicled graft was used for left internal mammary artery to the left anterior descending artery (LIMA-LAD) anastomosis. After rewarming and removing the cross clamp, the proximal anastomoses were performed on the ascending aorta with a side biting clamp; one anastomosis for sequential conduit cases and two, for individual conduits. Average cross clamp time was 47 min and average time on pump was 92 min. The suture material used was 7,0 blue monofilament polypropylene, double armed, for the distal anastomoses and 6,0 blue monofilament polypropylene, double armed, for the proximal anastomoses. The most distal anastomosis on a sequential graft was done in end-to-side fashion. OM anastomoses were constructed side-to-side. Side-to-side anastomoses were done in a diamond-shape (graft axis perpendicular to coronary arteriotomy) and end-to-side anastomoses were done parallel to the native coronary vessel axis.

2.1.1. Group A

Total number of patients who underwent sequential grafting was 151; each patient had two distal anastomoses performed with the sequential saphenous venous conduit - one in the left circumflex artery (LCX) system (Obtuse marginal, either OM 1 or OM 2), and the other in the posterior descending artery (PDA). The proximal anastomosis was done on the ascending aorta. The third anastomosis in each patient was the left internal mammary artery to the left anterior descending artery (LIMA-LAD). Hence the total number of distal anastomoses performed on each patient with the venous conduit was 2, totally 302 for 151 patients.

2.1.2. Group B

Total number of patients who underwent individual venous grafting was 172; each patient had two anastomoses performed with two individual saphenous venous conduits - one in the left circumflex artery (LCX) system (Obtuse marginal, either OM 1 or OM 2), and the other in the posterior descending artery (PDA). Two proximal

anastomoses were done on the ascending aorta. The third distal anastomosis in each patient was the LIMA-LAD. Hence the total number of distal anastomoses performed on 172 patients, with the individual venous conduits, was 344.

The total number of distal anastomoses performed using venous conduits was $302 + 344 = 646$. If we take the LIMA-LAD anastomoses into account for all the patients, along with the anastomoses performed with venous conduits, then the total number of distal anastomoses performed for all patients is $646 + 151 + 172 = 969$. We have not taken into account the proximal anastomoses.

The patients were discharged by the tenth post operative day, and were followed up from post operative day 15 till date.

2.2. Coronary angiograms

Angiograms were performed at six months, and one, two and three years post operatively. For symptomatic patients post CABG, emergency angiograms were performed. Any emergency angiogram that was done in the interim period between two scheduled angiograms, had its results incorporated in the next scheduled one. The angiograms documented the flow in the conduits, the patency of the conduits and the patency at the anastomotic sites. Proper consent was obtained prior to the invasive modality. Venous conduits were categorized as follows:

- I) patent: no stenosis;
- II) occluded: non-opacified graft;
- III) partially patent: hemodynamically significant (>50%) stenosis, and/or newly developed plaques and/or one open anastomosis through a sequential graft. Graft patency rates included both patent and partially patent grafts.

Anastomotic patency rates were documented for each vessel group or coronary artery system; circumflex, PDA and LAD.

3. Results

The follow up duration has been the maximum for the patients operated in 2014, till date. The last patient considered for the study was operated in June 2017. We are presenting the conduit and anastomotic patency results for the patients who had been operated in 2014–2017.

Each patient underwent 3 distal anastomoses - LIMA-LAD, saphenous venous graft (SVG) - OM₁/OM₂ (any one) and SVG-PDA.

Total number of patients who underwent sequential SVG grafting was 151 - Group A.

Total number of patients who underwent individual SVG grafting was 172 - Group B.

Total number of anastomoses of sequential SVG grafting - 302 (151 grafts), 151 in OM₁/OM₂, 151 in PDA.

Total number of anastomoses of individual SVG grafts - 344 (344 grafts), 172 in OM₁/OM₂, 172 in PDA.

Total number of LIMA-LAD anastomoses - 323.

Hence, the total number of anastomoses evaluated (distal) for all patients = 302 + 344+323 = 969.

3.1. Statistical analysis: using SPSS, documented in the figures and tables section

We observed that:

- i) Sequential conduits tend to have better mid-term patency than individual ones, though the difference is not conspicuous in the initial post operative period, viz. 6 months (Tables IA, IB, IC and ID).
- ii) Anastomoses on the sequential conduits have better mid-term patency than individual conduits, irrespective of the location of anastomoses, except in the initial period, viz 6 months (Tables IIAi, IIAii, IIBi, IIBii, IICi, IICii, IIDi, IIDii).
- iii) Comparison of anastomoses on the PDA system and Cx system (irrespective of the type of conduit), did not lead to conclusive data; requires long term follow up (Tables IIIA, IIIB, IIIC, IIID).

Totally, 67 patients left the study during the course of follow up of 3 years. 11 patients left post complete occlusion of LIMA only, due to presentation in the form of angina or acute coronary syndrome (ACS), when they were managed by graft intervention (redo CABG in 3, percutaneous coronary intervention (PCI) in 8 [10,11]). Post repeat revascularisation their clinical course was uneventful. 4 patients expired post complete single LIMA graft occlusion due to myocardial infarction. 4 patients had symptoms due to both LIMA and SVG graft occlusion, they were managed by PCI. Out of the remaining 48 patients, 10 patients died due to SVG graft occlusion and 38 had angina, ACS, heart failure or arrhythmias, managed by medication and PCI. Total mortality was 14 (4.33%).

4. Discussion

The use of side-to-side anastomoses between veins and additional coronary branches was described by

Flemma and colleagues in 1971 [12] and reported in more detail a year later by Bartley and colleagues [13]. Sequential vein grafts have been criticized because occlusion in the most proximal anastomosis may affect several coronary branches and that will result in a large area involving myocardial infarction and jeopardise the patient's life [14]. However, more authors did not agree with the opinion above. They found that a proximal occlusion of a sequential vein bypass might cause renewed angina, but without infarction in most instances [9,15]. The hypothesis was that in case of a proximal occlusion, the sequential conduit will function as a large collateral vessel [2]. O'Neill and colleagues [16] reported that the proximal segment of the sequential bypass graft has a higher velocity of blood flow than that seen in a single bypass graft, hence a decreased total resistance to graft flow, minimal impedance mismatch, and good long-term patency rate [2]. According to Rittgers et al. [17], there is a reverse relationship between the flow rate and intimal proliferation; increased flow rate transpires into a lesser rate of proliferation. Faulkner et al. [18] also reported that an increased flow rate was associated with less intimal proliferation.

The diameters of SVG segments are relatively constant for a given patient. Also, the resistance posed by the former is negligible when compared to that of its coronary counterpart and hence the native coronary vessel's resistance remains as the principal determinant of the flow rate. If we assume individual resistances of the grafted coronary arteries to be equivalent, a double sequential graft possesses only half of the resistance of an individual graft. Thus, the individual SVGs are more resistant than the sequential ones [16,19,20].

This brings us to the rationale behind our study. There has been no similar study that has been carried out in the Indian population (though a few Chinese and Korean studies can be accessed) [1,2,21]. As per separate studies conducted by Makaryus et al. [22], and G Y H Lip et al. [23], the coronary arteries of Asian-Indian patients show statistically significantly smaller values in the mean diameters of the coronaries as compared with Caucasians; the values of the mean diameters were, left main (2.96 mm vs 4.04 mm, $p = 0.0004$), left anterior descending (2.48 mm vs 3.24 mm, $p = 0.0005$), left circumflex (2.52 mm vs 3.06 mm, $p = 0.00002$), and right coronary artery (2.71 mm vs 3.65 mm, $p = 0.0008$) as compared with Caucasians. Smaller diameters lead to more effects on flow than the same degree of stenosis in vessels of larger diameters, as the cross-sectional area would be highly reduced in the former. Thus, a moderate plaque

would cause a more significant obstruction in a small vessel [23] and increased resistance by the narrow coronaries. In this scenario, taking the study by Rittgers et al. into consideration, we had hypothesised that an increased flow rate, thus enabling reduced resistance, is essential to ensure prolonged patency in narrower coronaries in the Indian context. The institutional study proved that the mid-term patency is better in case of sequential SVG conduits than the individual ones. Our results are specifically relevant, especially as coronary artery disease is on the brink of an epidemic in the Indian subcontinent, and we need to swiftly document preferred CABG protocols [24], that are alarmingly non-existent. Our studies are still underway and long term patencies shall be documented in due course.

Conclusion: Sequential bypass grafts were associated with superior mid-term patency compared with individual grafts, in line with a significant number of studies in the West. Indian data is specifically relevant due to the increasing number of cases and the presence of narrower coronaries.

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Author contributions

Manoj M. Joshi: Conception and design of Study; Literature review; Acquisition of data; Revising and editing the manuscript critically for important intellectual contents; Data preparation and presentation; Supervision of the research; Research coordination and management; Funding for the research.

Saptarshi Paul: Conception and design of Study; Literature review; Research investigation and analysis; Data collection; Drafting of manuscript; Revising and editing the manuscript critically for important intellectual contents; Data preparation and presentation; Supervision of the research; Research coordination and management; Funding for the research.

Krishnarao N. Bhosle: Literature review; Acquisition of data; Research investigation and analysis; Revising and editing the manuscript critically for important intellectual contents; Supervision of the research; Research coordination and management.

Suraj W. Nagre: Literature review; Research investigation and analysis; Drafting of manuscript; Revising and editing the manuscript critically for important intellectual contents; Funding for the research.

Hrishikesh Parashi: Literature review; Acquisition of data; Research investigation and analysis; Data collection; Drafting of manuscript; Revising and editing the manuscript critically for important intellectual contents; Funding for the research.

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Joshua A Selwyn: Acquisition of data; Data collection; Drafting of manuscript; Funding for the research.

Conflict of interest

None declared.

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