OPEN AIMJ ORIGINAL ARTICLE

Cardio-Thoracic Surgery

Comparative Study of Total Arterial Revascularization versus Conventional Coronary Artery Bypass Grafting

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Received *for publication June 19, 2022;* ***Accepted*** *December 31, 2022;* ***Published online*** *December 31, 2022.*

Citation: *Mohamed K., Salaheddin S, and Mohamed K. The Surgical Outcome of Chronic Rhinosinusitis with Emphasis on Rhinogenic Headache. AIMJ. 2022; Vol.3-Issue 12 : 74-79.*

doi: 10.21608/aimj.2022.145749.2005

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ABSTRACT

Background: The superiority of total arterial revascularization over the conventional method is a matter of continuous debate.

Aim of the study: To compare early surgical and hospital outcomes of the total artery and conventional revascularization strategies in patients undergoing coronary artery bypass grafting (CABG).

Patients and Methods: The study included 60 patients who underwent primary elective CABG from 2018 to 2020. Patients were grouped according to the revascularization strategy into two groups. Group 1 included patients who had conventional revascularization using left internal mammary artery (LIMA) and vein grafts (n= 30), and group 2 included patients who had total arterial coronary revascularization (TACR) (n= 30).

Result: Patient who had TACR were significantly younger (48.43 ± 11.72 vs. 55.63 ± 3.97 years; P= 0.003). TACR patients had shorter cardiopulmonary bypass (53.70 ± 9.91 vs 61.83 ± 9.60 min; P= 0.002) and ischemia times (38.20 ± 7.78 vs 44.03 ± 7.23 min; P= 0.004). Blood loss and transfusion were significantly higher in patients in the conventional group (P= 0.01 and <0.001, respectively). TACR was associated with shorter mechanical ventilation (3.83 ± 0.95 vs. 4.80 ± 1.40 hours; P= 0.003), ICU (1.13 ± 0.35 vs. 1.47 ± 0.51 days; P= 0.004) and hospital stay (4.47 ± 0.63 vs. 6.04 ± 0.71 days; P= 0.001). After six months, angina and dyspnea classes were significantly better in the TACR group.

Conclusion: The debate about the optimal CABG conduit is ongoing. Total arterial revascularization could be associated with favorable short and mid-term results.

Keywords: *Coronary artery bypass grafting; Total arterial revascularization; Left internal mammary artery; Radial artery.*

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.*

Authorship: *All authors have a substantial contribution to the article.*

INTRODUCTION

Coronary artery bypass grafting (CABG) is the most commonly performed cardiac surgical procedure.[1] Moreover, CABG remains the most effective revascularization strategy for severe coronary atherosclerotic disease[2] and in patients with diabetes, left main and three vessels disease.[3] The debate about the optimal conduit for CABG is still going on, and choosing the proper graft affects CABG's short and long-term outcomes. Graft patency is related to the smooth postoperative course and enhances patients' survival and freedom from coronary reintervention.

Long saphenous vein graft has been the preferred conduit for a long time; however, progressive vein graft failure negatively affects the long-term outcomes after CABG.[4] Total arterial revascularization has emerged as an alternative solution to improve the long-term outcomes after CABG.[5] The superiority of total arterial revascularization over conventional methods is a subject of continuous debate.

Therefore, we aimed to compare early surgical and hospital outcomes of the total artery and conventional revascularization strategies in patients undergoing CABG.

PATIENTS AND METHODS

Design and patients

This retrospective cohort research comprised 60 patients who underwent primary CABG at Cardiothoracic Surgery Departments, Faculty of Medicine, Al-Azhar University, between 2018 and 2020. We included patients who had elective on-pump CABG. Patients who underwent emergency CABG, or those with poor left ventricular ejection

fraction (EF< 35%), redo CABG, concomitant procedure, and end-organ dysfunction or previous stroke were excluded. Patients were grouped according to the revascularization strategy into two groups. Group 1 included patients who had conventional revascularization using left internal mammary artery (LIMA) and vein grafts (n= 30), and group 2 included patients who had total arterial coronary revascularization (TACR) (n= 30). Patients were assigned to each group according to the surgeons' preferences and experience.

The study was approved by the local Ethical Committee, and the need for patients' consent was waived because of the retrospective design.

Data and outcomes

All patients were subjected to full history taking, preoperative laboratory tests, chest x-ray, ECG, echocardiography, and coronary angiography. Operative data included the number of anastomoses, graft, coronary size, anastomosis technique, and operative, cardiopulmonary bypass (CPB), and cross-clamp times. Intraoperative events included using inotropes, defibrillator, intra-aortic balloon pump, and mortality. Postoperative outcomes included cardiac output, cardiac index, postoperative inotropes, blood loss, blood transfusion, hospital complications, length of intensive care unit stay (ICU), and hospital stay and mortality. Patients were followed for six months after surgery at the outpatient clinic. Follow-up data included angina and dyspnea status, EF, and wall motion index. Wall motion index was evaluated in echocardiography in 16 segments. Segmental wall motion was classified into normal (= 1), hypokinetic (=2), akinetic (= 3), and dyskinetic (=4).[6]

Operative techniques

All patients had surgery via median sternotomy. Arterial cannulation was performed through the ascending aorta and venous cannulation through the right atrium. In patients with conventional CABG, LIMA was anastomosed to the left anterior descending artery (LAD) and saphenous vein to other targets. In the TACR group, LIMA was used for LAD, and the right internal mammary (RIMA) or radial artery was used for other grafts. The patency of the grafts was assessed using a transient time flow meter (TTFM), and the mean flow (MF) and pulsatile index (PI) were reported.

Statistical analysis

A normality test, the Kolmogorov-Smirnov test, was used to measure the data distribution. Accordingly, a comparison between normally distributed variables in the two groups was performed using an unpaired t-test. A comparison between non-normally distributed variables was performed using the Mann-Whitney test. Continuous data were expressed as mean and standard deviation, and categorical data as numbers and frequencies. Statistical Package for Social Sciences (SPSS) computer program (version 19 windows, IBM Corp, Armonk, NY, USA) was used for data analysis. A P value of <0.05 was considered significant.

RESULTS

Preoperative data

Patients who underwent TACR were significantly younger (*P*= 0.003). There were no differences in gender, weight, and height between groups. Dyspnea class III and hypertension were more prevalent in patients in the TACR group, with no difference in angina class or other comorbidities between groups. Preoperative antiplatelets were significantly higher in patients who underwent TACR, with a significantly higher prevalence of stable angina. There was no difference in ejection fraction between groups; however, left ventricular end-diastolic diameter was significantly higher in patients in the TACR group. (Table 1)

	Group 1 (n= 30)	Group 2 (n= 30)	*P*-value
Age at surgery (y)	55.63 ± 3.97	48.43 ± 11.72	0.003
Male	27 (90.0%)	24 (80.0%)	0.28
Weight (kg)	84.43 ± 6.97	83.60 ± 5.30	0.60
Height (cm)	172.60 ± 6.32	172.50 ± 5.56	0.95
Angina status			
CCS II	3 (10.0%)	7 (23.3%)	0.17
CCS III	27 (90.0%)	23 (76.7%)	
Dyspnea status			
NYHA I	0 (0.0%)	2(6.7%)	0.02
NYHA II	6 (20.0%)	0 (0.0%)	
NYHA III	24 (80.0%)	28 (93.3%)	
Diabetes mellitus	17 (56.7%)	15 (50.0%)	0.61
Hypercholesterolaemia	9 (30.0%)	9 (30.0%)	<0.99
Hypertension	9 (30.0%)	20 (66.7%)	0.004
Smoking	22 (73.3%)	18 (60.0%)	0.27
Antiplatelets	19 (63.3%)	30 (100.0%)	0.001
Coronary artery disease			
Recent myocardial infarction	17 (56.7%)	8 (26.7%)	0.02

Unstable angina	13 (43.3%)	22 (73.3%)	
Ejection Fraction (%)			
Fair (30-49%)	11 (36.7%)	12 (40.0%)	0.79
Good (>50%)	19 (63.3%)	18 (60.0%)	
LVEDD	4.30 ± 0.35	4.53 ± 0.39	0.02
LVESD	3.13 ± 0.43	3.32 ± 0.44	0.09
AHA heart failure classification			
Stage A	13 (43.3%)	15 (50.0%)	0.61
Stage B	17 (56.7%)	15 (50.0%)	

(AHA: American Heart Association; CCS: Canadian Cardiovascular Society; LEVEDD: left ventricular end-diastolic diameter; LVESD: left ventricular end-systolic diameter; NYHA: New York Heart Association)
(Continuous data were presented as mean and standard deviation and categorical data as numbers and frequencies)

Table 1: Comparison of the preoperative data between patients who had conventional versus total arterial revascularization (Group 1: conventional coronary artery bypass grafting; Group 2: total arterial revascularization)

Operative data

The number of distal anastomoses was significantly higher in patients with conventional CABG ($P< 0.001$). The most common graft conduit used in the total arterial revascularization group was pedicled LIMA (46.9%), followed by radial artery (26.6%), then pedicled RIMA (20.3%), and skeletonized RIMA (6.2%). In comparison, long SV was the most common graft used in the conventional group (63%), followed by pedicled LIMA (34.6%) and pedicle RIMA (2.5%).

The most common graft site in the TACR group was the LAD (46.9%), followed by first obtuse marginal branches (OM1) (26.6%), then the right coronary artery (RCA) (20.3%), and ramus site (6.2%). Similarly, LAD was the most common graft site used in the conventional group (37.0%), followed by RCA (29.6%), OM1 (23.5%), and first diagonal branch (D1) (9.9%). The side-to-side anastomosis was done in six cases (9.4%) in the TACR group, while all patients in the conventional group had an end-to-side anastomosis ($P<0.01$). The mean flow and coronary size were significantly higher in the TACR group compared to the conventional group.

Cardiopulmonary bypass and ischemic times were significantly longer in patients with conventional CABG, while there was no difference between groups in the operative time. (Table 2)

	Group 1 (n= 81)	Group 2 (n= 64)	*P* value
Number of distal coronary anastomosis			
Two	28 (34.6%)	52 (81.2%)	
Three	33 (40.7%)	12 (18.8%)	<0.001
Four	20 (24.7%)	0 (0.0%)	
Graft conduit			
Free right internal mammary artery	0 (0.0%)	4 (6.2%)	
Long saphenous vein	51 (63.0%)	0 (0.0%)	
Pedicled left internal mammary artery	28 (34.6%)	30 (46.9%)	0.03
Pedicled right internal mammary artery	2 (2.5%)	13 (20.3%)	
Radial artery	0 (0.0%)	17 (26.6%)	
Graft site			
First diagonal	8 (9.9%)	0 (0.0%)	
Left anterior descending	30 (37.0%)	30 (46.9%)	
Obtuse marginal	19 (23.5%)	17 (26.6%)	0.01
Right coronary artery	24 (29.6%)	13 (20.3%)	
Ramus	0 (0.0%)	4 (6.2%)	
Anastomosis			
End-to-side	81 (100.0%)	58 (90.6%)	0.01
Side-to-side	0 (0.0%)	6 (9.4%)	
Mean flow (ml/min)	41.37 ± 7.35	46.27 ± 5.12	<0.001
Pulsatile index	2.90 ± 0.34	2.85 ± 0.31	0.33
Coronary size (mm)	1.34 ± 0.22	1.42 ± 0.18	0.02
Operative time (min)	180.20 ± 12.57	178.13 ± 8.88	0.465
Cardiopulmonary bypass time (min)	61.83 ± 9.60	53.70 ± 9.91	0.002
Ischemia time (min)	44.03 ± 7.23	38.20 ± 7.78	0.004
Intraoperative inotropes	6 (20.0%)	4 (13.3%)	0.49
Defibrillator use	11 (36.7%)	8 (26.7%)	0.40

Table 2: Comparison of the operative data between patients who had conventional versus total arterial revascularization (Group 1: conventional coronary artery bypass grafting; Group 2: total arterial revascularization)

Postoperative outcomes

There were no differences in cardiac output and index between groups. There was lower blood loss and fewer fresh frozen plasma and platelets units used in the TACR group compared to the conventional group. Duration of mechanical ventilation, ICU, and hospital stay were significantly longer in the conventional group. (Table 3) We did not report sternal wound infection or hospital mortality in our cohort.

	Group 1 (n= 30)	Group 2 (n= 30)	*P*- value
Cardiac output (L/min)	4.89 ± 0.42	4.88 ± 0.41	0.93
Cardiac index (L/m/m2)	2.40 ± 0.26	2.48 ± 0.22	0.18
Postop inotropes	3 (10.0%)	0 (0.0%)	0.08
Blood loss	530.33 ± 187.52	422.0 ± 129.81	0.01
Blood units	1.68 ± 0.82	0.73 ± 0.69	<0.001
Fresh frozen plasma units	5 (16.7%)	2 (6.7%)	0.23
Platelets units	12 (40.0%)	8 (26.7%)	0.27
Mechanical ventilation (hours)	4.80 ± 1.40	3.83 ± 0.95	0.003
ICU stay (days)	1.47 ± 0.51	1.13 ± 0.35	0.004
Hospital stay (days)	6.04 ± 0.71	4.47 ± 0.63	0.001
Atelectasis	3 (10.0%)	0 (0.0%)	0.08

Table 3: Comparison of the postoperative data between patients who had conventional versus total arterial revascularization (Group 1: conventional coronary artery bypass grafting; Group 2: total arterial revascularization)

Follow-up data

After six months, angina and dyspnea classes were significantly better in the total revascularization group. There was no difference in EF between groups, and the wall motion index was significantly lower in the TACR group. (Table 4)

	Group 1 (n= 30)	Group 2 (n= 30)	*P*-value
Angina status			
CCS 0	24 (80.0%)	30 (100.0%)	0.01
CCS I	6 (20.0%)	0 (0.0%)	
Dyspnea status			
NYHA I	21 (70.0%)	30 (100.0%)	0.001
NYHA II	9 (30.0%)	0 (0.0%)	
Ejection fraction (%)			
Fair (30-49%)	11 (36.7%)	12 (40.0%)	0.791
Good (>50%)	19 (63.3%)	18 (60.0%)	
Wall motion score index	1.70 ± 0.25	1.50 ± 0.00	0.001

Table 4: Comparison of the 6-months follow-up data between patients who had conventional versus total arterial revascularization (Group 1: conventional coronary artery bypass grafting; Group 2: total arterial revascularization)

DISCUSSION

The conduits used for CABG greatly impact the outcomes of surgery, and graft patency is the major determinant of the postoperative and long-term outcomes.[7] Total arterial revascularization became an alternate option to saphenous vein grafts to improve the long-term outcomes after CABG; however, the superiority of this approach is still debated.[8] Total arterial revascularization has the potential advantage of a better patency rate, lower myocardial infarctions and reoperations, and a better survival rate.[9]

This study compared total arterial revascularization strategy and conventional CABG with long saphenous vein grafts. Patients who had TACR were younger, which could be attributed to assigning young patients to this group to benefit from the long-term patency of the arterial grafts.[10,11]

The most common graft used in the TACR group was pedicled LIMA (46.9%), while the long saphenous vein was the most common graft used in the conventional group (63%). The mean flow and coronary size were higher in the TACR group. LIMA is the most common conduit for CABG. Tabata and associates reported that LIMA was used in 48% to 100% of CABG patients in a multicenter study on 541,368 CABG patients.[12] Moreover, LIMA was an independent predictor of survival and better long-term outcomes compared to saphenous vein grafts.[13]

RIMA was not used frequently in our study and is usually used as bilateral mammary conduits. Several studies showed that RIMA was associated with better long-term outcomes compared to other conduits.[13,14] Goldstone and associates found that RIMA was associated with increased sternal wound infections and offered no advantages over the radial artery.[15] RIMA was also associated with increased operative time, bleeding, and preoperative morbidity.[16,17]

The radial artery was used in CABG with superior results compared to the saphenous vein.[18,19] The radial artery is resistant to atherosclerosis and allows parallel LIMA harvesting.[3] However, its muscular wall and liability to spasms make surgeons resistant to using it. Several studies reported improved survival with radial artery grafts.[20,21] Zacharias and colleagues found that LIMA and RA grafts were

associated with better survival compared to LIMA and saphenous vein grafts.[22] In another study by Hayward and associates, 7-year survival was similar in patients with radial artery grafts compared to the saphenous vein.[23]

Another option for total arterial revascularization is to use the free IMA. Several studies demonstrated a comparable patency rate between the free graft and pedicled LIMA. Still, data about the long-term outcomes and graft failure are inconclusive, and the pedicled technique remains the conventional method.[24,25]

The total arterial revascularization technique was more acceptable than the conventional one as the former has a shorter cardiopulmonary bypass (53.70 ± 9.91 vs. 61.83 ± 9.60 min; *P*= 0.004) and ischemia times (38.20 ± 7.78 vs. 44.03 ± 7.23 min; *P*= 0.002). In agreement with our findings, Obed and colleagues reported shorter operative, cardiopulmonary bypass, aortic cross-clamp, and ventilation times in the TACR group. Additionally, hospital and intensive care unit stays were significantly shorter in the TACR group.[3]

We reported lower blood loss and fewer blood units, fresh frozen plasma, and platelets units in the TACR group compared to the conventional group. That finding is in agreement with other studies.[3,20,21] Moreover, we found no statistically significant differences between both groups regarding postoperative cardiac-related events. In agreement with our results, Le and coworkers found no difference in in-hospital mortality, stroke, or sternal wound infection between the two groups.[26] Obed and associates found no difference in myocardial infarction, neurological complications, wound infection, and prolonged ventilation between both groups.[3] In a randomized trial by Muneretto and associates, they reported no difference in sternal wound infection between total arterial revascularization and conventional CABG, and the myocardial adverse events were higher in the conventional CABG group.[27]

In our study, patients in the TACR group have shorter ventilation time, ICU, and hospital stays than conventional patients. During follow-up of patients of both groups, patients in the TACR group were rapidly returned to a class of no symptoms according to CCS and NYHA classification. Previous studies showed that using saphenous vein grafts predicted recurrent angina and graft occlusion.[27] The current study recorded no hospital mortality among the studied patients. Most studies reported a 1% mortality rate with no difference between both techniques.[15,27]

Study limitations

The study has several limitations, including the retrospective design, single-center experience, and small patient number. The preoperative patient characteristics could have affected assigning patients to different groups and, consequently, the outcomes. The study is limited by the short-term follow up.

CONCLUSION

The debate about the optimal CABG conduit is ongoing. Total arterial revascularization could be associated with favorable short and mid-term results. Further studies comparing both techniques are still recommended.

Conflict of interest : none

REFERENCES

1. Head SJ, Milojevic M, Taggart DP, Puskas JD. Current Practice of State-of-the-Art Surgical Coronary Revascularization. Circulation. 2017 Oct;136(14):1331–45.

2. Timmis A, Townsend N, Gale C, Grobbee R, Maniadakis N, Flather M, et al. European Society of Cardiology: Cardiovascular Disease Statistics 2017. Eur Heart J. 2018 Feb;39(7):508–79.

3. Obed D, Fleissner F, Martens A, Cebotari S, Haverich A, Warnecke G, et al. Total Arterial Revascularization with Radial Artery and Internal Thoracic Artery T-Grafts Is Associated with Superior Long-Term Survival in Patients Undergoing Coronary Artery Bypass Grafting. Ann Thorac Cardiovasc Surg Off J Assoc Thorac Cardiovasc Surg Asia. 2020 Feb;26(1):30–9.

4. Schwann TA. The Surgical Treatment of Coronary Artery Occlusive Disease: Modern Treatment Strategies for an Age Old Problem. Surg Clin North Am. 2017 Aug;97(4):835–65.

5. Raja SG. Composite arterial grafting. Expert Rev Cardiovasc Ther. 2006 Jul;4(4):523–33.

6. Cerqueira MD, Weissman NJ, Dilsizian V, Jacobs AK, Kaul S, Laskey WK, et al. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart. A statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. Circulation. 2002 Jan;105(4):539–42.

7. Rayol SC, Van den Eynde J, Cavalcanti LRP, Escorel ACN, Rad AA, Amabile A, et al. Total Arterial Coronary Bypass Graft Surgery is Associated with Better Long-Term Survival in Patients with Multivessel Coronary Artery Disease: a Systematic Review with Meta-Analysis. Brazilian J Cardiovasc Surg. 2021 Feb;36(1):78–85.

8. Raja SG. Total arterial coronary grafting: outcomes, concerns and controversies. Vessel Plus [Internet]. 2019;3:23. Available from: http://dx.doi.org/10.20517/2574-1209.2019.05

9. Rocha R V, Tam DY, Karkhanis R, Wang X, Austin PC, Ko DT, et al. Long-term Outcomes Associated With Total Arterial Revascularization vs Non-Total Arterial Revascularization. JAMA Cardiol. 2020

May;5(5):507–14.

10. Habib RH, Dimitrova KR, Badour SA, Yammine MB, El-Hage-Sleiman A-KM, Hoffman DM, et al. CABG Versus PCI: Greater Benefit in Long-Term Outcomes With Multiple Arterial Bypass Grafting. J Am Coll Cardiol. 2015 Sep;66(13):1417–27.

11. Taggart DP. How I deploy arterial grafts. Ann Cardiothorac Surg. 2018 Sep;7(5):690–7.

12. Tabata M, Grab JD, Khalpey Z, Edwards FH, O'Brien SM, Cohn LH, et al. Prevalence and variability of internal mammary artery graft use in contemporary multivessel coronary artery bypass graft surgery: analysis of the Society of Thoracic Surgeons National Cardiac Database. Circulation. 2009 Sep;120(11):935–40.

13. Buttar SN, Yan TD, Taggart DP, Tian DH. Long-term and short-term outcomes of using bilateral internal mammary artery grafting versus left internal mammary artery grafting: a meta-analysis. Heart. 2017 Sep;103(18):1419–26.

14. Bayer N, Hart WM, Arulampalam T, Hamilton C, Schmoeckel M. Is the Use of BIMA in CABG Sub-Optimal? A Review of the Current Clinical and Economic Evidence Including Innovative Approaches to the Management of Mediastinitis. Ann Thorac Cardiovasc Surg Off J Assoc Thorac Cardiovasc Surg Asia. 2020 Oct;26(5):229–39.

15. Goldstone AB, Chiu P, Baiocchi M, Wang H, Lingala B, Boyd JH, et al. Second Arterial Versus Venous Conduits for Multivessel Coronary Artery Bypass Surgery in California. Circulation. 2018 Apr;137(16):1698–707.

16. Gansera B, Schmidtler F, Gillrath G, Angelis I, Wenke K, Weingartner J, et al. Does bilateral ITA grafting increase perioperative complications? Outcome of 4462 patients with bilateral versus 4204 patients with single ITA bypass. Eur J cardio-thoracic Surg Off J Eur Assoc Cardio-thoracic Surg. 2006 Aug;30(2):318–23.

17. Tatoulis J, Wynne R, Skillington PD, Buxton BF. Total Arterial Revascularization: Achievable and Prognostically Effective-A Multicenter Analysis. Ann Thorac Surg. 2015 Oct;100(4):1268–75; discussion 1275.

18. Athanasiou T, Saso S, Rao C, Vecht J, Grapsa J, Dunning J, et al. Radial artery versus saphenous vein conduits for coronary artery bypass surgery: forty years of competition--which conduit offers better patency? A systematic review and meta-analysis. Eur J cardio-thoracic Surg Off J Eur Assoc Cardio-thoracic Surg. 2011 Jul;40(1):208–20.

19. Cao C, Manganas C, Bannon P, Vallely M, Yan TD. Drug-eluting stents versus coronary artery bypass graft surgery in left main coronary artery disease: a meta-analysis of early outcomes from randomized and nonrandomized studies. J Thorac Cardiovasc Surg. 2013 Mar;145(3):738–47.

20. Fleissner F, Engelke H, Rojas-Hernandez S, Ismail I, Stiefel P, Cebotari S, et al. Long-term follow-up of total arterial revascularization with left internal thoracic artery and radial artery T-grafts: survival, cardiac morbidity and quality of life. Eur J cardio-thoracic Surg Off J Eur Assoc Cardio-thoracic Surg. 2016 Apr;49(4):1195–200.

21. Shi WY, Tatoulis J, Newcomb AE, Rosalion A, Fuller JA, Buxton BF. Is a third arterial conduit necessary? Comparison of the radial artery and saphenous vein in patients receiving bilateral internal thoracic arteries for triple vessel coronary disease. Eur J cardio-thoracic Surg Off J Eur Assoc Cardio-thoracic Surg. 2016 Jul;50(1):53–60.

22. Zacharias A, Schwann TA, Riordan CJ, Durham SJ, Shah AS, Habib RH. Late results of conventional versus all-arterial revascularization based on internal thoracic and radial artery grafting. Ann Thorac Surg. 2009 Jan;87(1):19-26.e2.

23. Hayward PA, Yap CH, Shi WY, Buxton BF, Dinh DT, Reid CM, et al. Does the addition of a radial artery graft improve survival after higher risk coronary artery bypass grafting? A propensity-score analysis of a multicentre database. Eur J cardio-thoracic Surg Off J Eur Assoc Cardio-thoracic Surg. 2013 Sep;44(3):495–7.

24. Yim D, Wong WYE, Fan KS, Harky A. Internal mammary harvesting: Techniques and evidence from the literature. J Card Surg. 2020 Apr;35(4):860–7.

25. Hu X, Zhao Q. Skeletonized internal thoracic artery harvest improves prognosis in high-risk population after coronary artery bypass surgery for good quality grafts. Ann Thorac Surg. 2011 Jul;92(1):48–58.

26. Le J, Baskett RJF, Buth KJ, Hirsch GM, Brydie A, Gayner R, et al. A pilot randomized controlled trial comparing CABG surgery performed with total arterial grafts or without. J Cardiothorac Surg. 2015 Jan;10:1.

27. Muneretto C, Bisleri G, Negri A, Manfredi J, Carone E, Morgan JA, et al. Left internal thoracic artery-radial artery composite grafts as the technique of choice for myocardial revascularization in elderly patients: a prospective randomized evaluation. J Thorac Cardiovasc Surg. 2004 Jan;127(1):179–84.