Is Single LIMA-LAD Bypass Appropriate for OPCAB Training?

Shiho Naito[1] Hermann Reichenspurner[1] Björn Sill[1]

[1] Department of Cardiovascular Surgery, University Heart and Vascular Center, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

Thorac Cardiovasc Surg

Address for correspondence Shiho Naito, MD, PhD, Department of Cardiovascular Surgery, University Heart and Vascular Center, University Medical Center Hamburg-Eppendorf, 20246 Hamburg, Germany (e-mail: shiho.naito@gmail.com).

Abstract

Background A significant impact of surgeons' experience on outcomes of off-pump coronary artery bypass (OPCAB) has been recognized through previous large-scale studies. However, a safe, effective, and concrete OPCAB training was yet to be identified. We evaluate a safety of our OPCAB training model with single left internal mammary artery (LIMA)–left anterior descending artery (LAD) as a reasonable first step.

Methods Between January 2010 and June 2019, 180 patients with an isolated single coronary bypass of the LAD using LIMA as an in situ graft via median sternotomy fulfilled the inclusion criteria. Coronary arterial bypass under cardiopulmonary bypass (CPB), utilizing other graft material, minimal invasive direct coronary arterial bypass through left-sided thoracotomy, and multiple diseased coronary artery disease were excluded. The primary outcome is an early postoperative outcome (major adverse cardiac and cerebrovascular events [MACCEs]: myocardial infarction, coronary re-revascularization, stroke, acute renal failure, and all causes of death) between residents in training under supervision (group 1: $n = 63$) and experienced surgeons (group 2: $n = 117$). Trainees were already experienced in on-pump coronary artery bypass grafting.

Results Preoperative variables were comparable. There was no significant difference in the rate of MACCEs between the two groups including hospital mortality ($p = 1.000$), perioperative myocardial infarction ($p = 0.246$), stroke ($p = 0.655$), and acute renal failure ($p = 0.175$).

Conclusion The early postoperative outcome of off-pump LIMA to the LAD performed by trainees was comparable to those by experienced surgeons. Single LIMA-LAD was safely performed by trainees under supervision without CPB. In order to master OPCAB technique, single LAD bypass might be a reasonable first step to get into touch with the technical characteristics of this special procedure.

Keywords
- off-pump coronary artery bypass
- training
- LIMA-LAD

received
September 5, 2023
accepted after revision
January 31, 2024
accepted manuscript online
February 2, 2024

Georg Thieme Verlag KG,
Rüdigerstraße 14,
70469 Stuttgart, Germany

DOI https://doi.org/10.1055/a-2260-5218.
ISSN 0171-6425.

Introduction

Coronary artery bypass grafting (CABG) is the most common operation performed in cardiac surgery.[1] Given the technical development and the increasing use of percutaneous coronary interventions (PCI) in patients with three-vessel and left main coronary artery disease, the number of surgical procedures markedly declined in the last decade.[1] Even high-risk patients with complex coronary artery disease are well treated by cardiologists. Off-pump coronary artery bypass (OPCAB) surgery, especially "aortic no-touch technique" might be a reasonable solution counteracting to the negative aspect of CABG with regard to neurologic complications and/or perioperative transfusion needs.[2]

However, real-world data revealed that this procedure is performed in a minority of specialized centers, and the quantity and ratio of OPCAB have decreased significantly in recent years.[3,4] A standardized teaching program can hardly be implied. On one hand, we face the competing, quality concern when compared to PCI, and on the other hand, there is a significant impact of a surgeon's experience on outcome. Therefore, for a young trainee, an establishment of systematic training curriculum is warranted. As a first step, single left internal mammary artery (LIMA) to the left anterior descending artery (LAD) in off-pump technique might be reasonable, in order to learn this technique with good vision of the surgical field by the teaching supervisor.

Our objective was to compare early hospital outcomes of single LIMA-LAD off-pump CABG between trainees and experienced consultant surgeons, to evaluate the safety and reproducibility in terms of training utility.

Methods

The retrospective analysis included patients with single coronary artery disease who underwent isolated single coronary revascularization using LIMA in situ for LAD stenosis between 2010 and 2019 at our institution. A total of 180 consecutive patients who received LIMA in situ for LAD in OPCAB were involved in this study. Exclusion criteria were CABG under cardiopulmonary bypass (CPB), utilizing other graft material, minimal invasive direct coronary artery bypass (MIDCAB) through left-sided thoracotomy, and multiple diseased coronary artery disease. The current 180 patients were not suitable for MIDCAB due to anatomical reason including obesity, intramural position of LAD, or diffuse disease or urgent situation of ischemic status. There was no conversion from off-pump to on-pump in this cohort. In-hospital outcome was compared between trainees (group 1: $n = 63$) and experienced surgeons (group 2: $n = 117$). Data acquisition and analysis was performed retrospectively and anonymized according to the principles of Declaration of Helsinki.

Definitions

OPCAB was defined as any CABG procedure without CPB. The primary end point of this analysis was major adverse cardiac and cerebrovascular event including all-cause mortality within 30 days after the procedure, postoperative myocardial infarction during hospital stay, major cerebral stroke, acute renal failure (Kidney Disease Improving Global Outcomes (KDIGO) classification stage 3),[5] and any postoperative re-revascularization (PCI or surgical revision). Postoperative re-revascularization was indicated after angiographic diagnosis. Postoperative myocardial infarction was defined as type 5 myocardial infarction in the "Third universal definition of myocardial infarction."[6] The secondary outcomes were resternotomy for excessive bleeding, number of transfused red blood cell units, length of the intensive care unit (ICU) and hospital stays, and postoperative wound infection.

Operative Technique

All cases were performed under general anesthesia and through a median sternotomy. After preparation of the LIMA conduit, the heart was positioned using an epicardial stitch and stabilized using a Medtronic Octopus device (Medtronic, Dublin, Ireland) during distal anastomoses. A distal LIMA in situ graft to LAD anastomosis was performed as a running suture with 8/0 Prolene using a coronary shunt and a blower mister. We utilize the transit time flow meters for every bypass. All anastomosis was completed if only the flow volume is more than 15 mL/min and the pulsatility index is less than 5.0. Eight trainees were involved in the study in the period. They were in the final 2 years of the cardiac surgery training program for German board-certified cardiac surgery and had enough experience in on-pump CABG (median procedures before off-pump surgery: 15). Trainees (group 1) performed distal anastomosis under direct supervision of experienced surgeon.

Statistical Analysis

Continuous variables are reported as mean ± standard deviation or median with interquartile range as properly. Categorical variables are expressed as proportions. Baseline differences between experienced surgeon and trainees were detected using the Student's *t*-test for normal distribution of continuous variables, the Mann–Whitney's test for unequally distributed continuous variables, and the Fisher's exact test for categorical variables.

Statistical significance was present when the two-tailed *p*-value was less than 0.05. All statistical analyses were performed using the statistical software SPSS (IBM SPSS Statistics for Windows, Version 27.0. IBM Corp., Armonk, New York, United States).

Results

Baseline Characteristics

Baseline characteristics of the study cohorts are summarized in ►**Table 1**. Preoperative characteristics were comparable except from seven redo procedures within the group 2 (experienced surgeon).

Primary Outcome

Intraoperative and postoperative variables are summarized in ►**Table 2**. There was no significant difference with regard to surgical revision between the two groups. The frequency

Table 1 Baseline characteristics

	Group 1: trainee ($n = 63$)	Group 2: experienced surgeon ($n = 117$)	*p*-Value
Age, mean ± SD	65 ± 12	68 ± 11	0.311
Male, *n* (%)	44 (70)	76 (65)	0.507
STS morbidity, median (IQR)	6.218 (3.964–8.708)	6.109 (4.446–8.324)	0.687
Prior CABG, *n* (%)	0	7 (6)	**0.048**
Prior PCI, *n* (%)	18 (29)	33 (28)	0.959
STEMI, *n* (%)	5 (8)	7 (6)	0.678
NSTEMI, *n* (%)	5 (8)	9 (8)	0.762
Extracardiac arteriopathy, *n* (%)	9 (14)	19 (16)	0.730
COPD, *n* (%)	6 (10)	12 (10)	0.876
Stroke/TIA, *n* (%)	2 (3)	10 (9)	0.168
Arterial hypertension, *n* (%)	56 (89)	94 (80)	0.142
Diabetes on insulin, *n* (%)	7 (11)	8 (7)	0.322
Dialysis, *n* (%)	1 (2)	0	0.124
Preoperative EF (%), mean ± SD	51 ± 11	51 ± 12	0.309
Urgency, *n* (%)	6 (10)	14 (12)	0.619

Abbreviations: CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; IQR, interquartile range; NSTEMI, non-ST-elevated myocardial infarction; PCI, percutaneous coronary intervention; SD, standard deviation; STEMI, ST-elevated myocardial infarction; STS, Society of Thoracic Surgeon; TIA, transient ischemic attack.
Note: Bold values are relevant in results.

of major stroke, renal failure, or postoperative myocardial infarction was higher in trainee group but did not reach any statistical significance. All three cases of postoperative myocardial infarction were in the LAD territory. There was one hospital death in group 2 due to perioperative myocardial infarction and cardiogenic shock under extracorporeal membrane oxygenation therapy. The patient received postoperative catheter intervention. This was a complex redo case 5 years after CABG and aortic valve replacement. After extreme elevation of cardiac enzyme or unstable hemodynamics, patients received coronary angiography and it revealed graft kinking or stenosis at the level of anastomotic site. These patients received surgical revision and all of them could leave the hospital without any other complications.

Secondary Outcome

The duration of ICU stay or hospital stay were comparable between the two groups. Postoperative bleeding and

Table 2 Intraoperative and postoperative variables

	Group 1: trainee ($n = 63$)	Group 2: experienced surgeon ($n = 117$)	*p*-Value
Procedure time, median (min) (IQR)	175 (135–190)	160 (120–196)	0.310
Transfusion (unit), median (IQR)	0 (0–0)	0 (0–0)	0.756
Ventilation time (h), median (IQR)	4.5 (3.3–7.2)	4.75 (3.3–8.0)	0.659
ICU stay (d), median (IQR)	2 (1–3)	1 (1–3)	0.843
Rethorax due to bleeding, *n* (%)	3 (7)	3 (5)	0.532
Wound infection, *n* (%)	2 (4)	2 (2)	0.533
Hospital death, *n* (%)	0	1 (1)	1.000
Surgical revision, *n* (%)	2 (3)	3 (3)	0.812
PCI, *n* (%)	1 (2)	1 (1)	0.655
Postoperative MI, *n* (%)	2 (3)	1 (1)	0.246
Stroke, *n* (%)	1 (2)	1 (1)	0.655
Renal failure (KDIGO 3), *n* (%)	1 (2)	0	0.175
Hospital stay, median (IQR)	7 (6–8)	7(6–8)	0.951

Abbreviations: ICU, intensive care unit; IQR, interquartile range; KDIGO, Kidney Disease Improving Global Outcomes classification; MI, myocardial infarction; PCI, percutaneous coronary intervention.

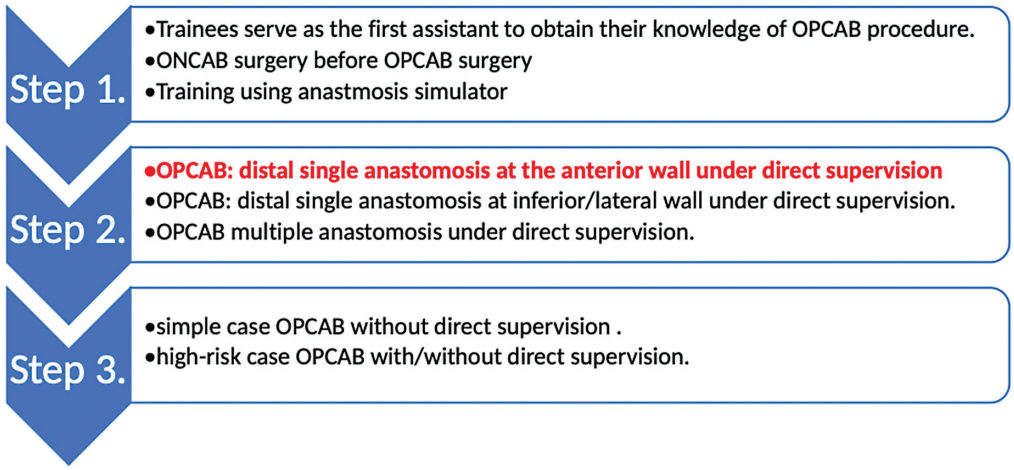

Fig. 1 OPCAB training model. ONCAB, on-pump coronary artery bypass; OPCAB, off-pump coronary artery bypass.

rethoracotomy were higher within the trainee group without any statistical significance. All postoperative wound infections were just superficial and were treated with vacuum-assisted closure therapy. There was no deep sternal wound infection.

Comments

The main finding of the present study is comparable early hospital outcome after single LIMA-LAD bypass in off-pump technique through trainees compared with experienced surgeons.

Previous Reports

Our finding is consistent with previous studies.[7,8] These previous studies comparing outcomes between consultants and trainees have been limited, in terms of a selection bias toward experienced surgeons operating more complex cases. Also, all OPCAB procedures with any bypass design were included. In our data, we simply analyze performed single LIMA-LAD series and add evidence of safety and reproducibility of the operation through young trainees.

Why Is OPCAB Needed?

The current guidelines recommend off-pump CABG for patients with significant atherosclerotic aortic disease (Class I, level B) or high risk (Class II, level B) by experienced off-pump teams.[9] Pros of this technique are to diminish any negative effect of CPB and aortic manipulation. Especially, cerebral events are the Achilles' heel of this type of surgery when compared to PCI. The etiology of postoperative neurological events after CABG is multifactorial. Air embolization, debris or clots from the CPB circuit, systemic inflammatory response, atherosclerotic plaques at the site of aortic manipulation, and intraoperative hypotension are the main mechanisms underlying neurological complications after cardiac surgery.[10] Therefore, CABG without any aortic manipulation, so-called aortic no-touch technique is a reasonable option to diminish these complications and its socioeconomic impacts on the patient. Further, several nonrandomized series show a significant reduction of early mortality of OPCAB group in reduced left ventricular ejection fraction patients.[11,12]

Experience on Outcome

The technical difference from on-pump CABG includes positioning and stabilization of the heart using a suction device, which might be unfamiliar to unexperienced surgeons. The distal anastomosis using a coronary artery shunt is markedly challenging comparing to on-pump surgery. Intraoperative hemodynamic instability must be managed together with anesthetists. The largest single randomized controlled trial ROOBY (Randomized On/Off Bypass trial[13]) failed to demonstrate improved outcomes in OPCAB. The main cause of failure might be inadequate surgeons' experience. Given the result, experience with OPCAB procedures seems to play a major role on outcome. Expertise and experience are crucial in this field.[2] Further, OPCAB is not an operation that is performed just occasionally by any surgeon in high-risk patients, but rather it needs to be on a routine basis by dedicated teams.[2]

Training Model

However, there is a huge niche between usual surgical training and routine OPCAB surgery as subspeciality. There is still no clear OPCAB training model. In spite of clear statement of guideline,[9] this procedure remains just a minority of specialized centers. Therefore, the establishment of exact OPCAB training model as subspeciality is warranted for young trainees. Hamburg OPCAB training model is shown in ►**Fig. 1**. After this results, we believe that this training model could be continued with safety and efficacy.

Simulator

Results of training using OPCAB simulator are sporadically reported.[14,15] Wu et al showed porcine beating heart simulator model.[14] Ito et al described the use of the "BEAT, YOU CAN" simulator (EBM, Tokyo, Japan) in training residents with no prior experience in CABG.[15] Simulator-oriented training enables improvement of forceps handling, positioning needles at a right angle, and focusing on target and graft vessels. Further, the reduction of procedural time will also be achieved. Concomitantly with on-site bypass training, these

simulator training will be helpful to get used to the technique earlier.

Limitation

This observational study has specific limitations. First, the main limiting aspect of our study is the small sample size of a single center, which might be consequently underpowered for important safety and efficacy end points. If the anatomical criteria reach the indication for minimally invasive surgery through left thoracotomy, the patients are operated not via median sternotomy, and only the remained cases were included for this cohorts. The single-center setting also reduces generalizability to broader clinical practice. Second, due to the low incidence of mortality or morbidity, the significant difference might not yet be present and risk factor analysis is not possible. Third, we evaluated just early postoperative outcomes, and no long-term data were included. Fourth, anatomical severity of LAD stenosis was not evaluated. In experienced group, there might be more complex cases including reoperation or severe embedded coronary artery influencing postoperative outcomes.

Conclusion

The early postoperative outcome off-pump LIMA to the LAD performed by trainees was comparable to experienced surgeons. Single LIMA-LAD was safely performed as training case under supervision without CPB. In order to master the demanding OPCAB technique, single LAD bypass might be an appropriate training case for young trainees to get used to the technical characteristics of this special procedure.

Authors' Contribution

S.N. and B.S. contributed to the conception of the project. S.N. created the figure, performed the statistical analysis, interpreted the data, and wrote the text. H.R. and B.S. revised the latest version of the manuscript.

Conflict of Interest

None declared.

References

1 Bowdish ME, D'Agostino RS, Thourani VH, et al. The Society of Thoracic Surgeons Adult Cardiac Surgery Database: 2020 update on outcomes and research. Ann Thorac Surg 2020;109(06):1646–1655

2 Rosati CM, Torregrossa G, Balkhy HH, Puskas JD. Dedicated training in advanced coronary surgery: need and opportunity. J Thorac Cardiovasc Surg 2021;161(06):2130–2134

3 Mack M, Taggart D. Coronary revascularization should be a subspecialty focus in cardiac surgery. J Thorac Cardiovasc Surg 2019;157(03):945–947

4 Ohri SK, Benedetto U, Luthra S, et al. Coronary artery bypass surgery in the UK, trends in activity and outcomes from a 15-year complete national series. Eur J Cardiothoracic Surg 2022;61(02): 449–456

5 Khwaja A. KDIGO clinical practice guidelines for acute kidney injury. Nephron Clin Pract 2012;120(04):c179–c184

6 Thygesen K, Alpert JS, Jaffe AS, et al; Joint ESC/ACCF/AHA/WHF Task Force for Universal Definition of Myocardial Infarction Authors/Task Force Members Chairpersons Biomarker Subcommittee ECG Subcommittee Imaging Subcommittee Classification Subcommittee Intervention Subcommittee Trials & Registries Subcommittee Trials & Registries Subcommittee Trials & Registries Subcommittee Trials & Registries Subcommittee ESC Committee for Practice Guidelines (CPG) Document Reviewers. Third universal definition of myocardial infarction. J Am Coll Cardiol 2012;60(16):1581–1598

7 Murzi M, Caputo M, Aresu G, Duggan S, Angelini GD. Training residents in off-pump coronary artery bypass surgery: a 14-year experience. J Thorac Cardiovasc Surg 2012;143(06):1247–1253

8 Pal S, Hartley P, Salmasi Y, Asimakopoulos G. Establishing the safety of training in off-pump coronary artery bypass surgery: a retrospective comparison of outcomes between trainees and a consultant surgeon. Thorac Cardiovasc Surg 2020;68(08): 674–678

9 Neumann FJ, Sousa-Uva M, Ahlsson A, et al. ESC/EACTS guidelines on myocardial revascularization. Vol. 40. Eur Heart J 2018; 2019:87–165

10 Caplan LR, Hennerici M. Impaired clearance of emboli (washout) is an important link between hypoperfusion, embolism, and ischemic stroke. Arch Neurol 1998;55(11):1475–1482

11 Ueki C, Miyata H, Motomura N, Sakaguchi G, Akimoto T, Takamoto S. Off-pump versus on-pump coronary artery bypass grafting in patients with left ventricular dysfunction. J Thorac Cardiovasc Surg 2016;151(04):1092–1098

12 Guan Z, Guan X, Gu K, et al. Short-term outcomes of on- vs off-pump coronary artery bypass grafting in patients with left ventricular dysfunction: a systematic review and meta-analysis. J Cardiothorac Surg 2020;15(01):84

13 Shroyer AL, Hattler B, Wagner TH, et al; Veterans Affairs ROOBY-FS Group. Five-year outcomes after on-pump and off-pump coronary-artery bypass. N Engl J Med 2017;377(07):623–632

14 Wu S, Ling Y-P, Zhao H. Experience with porcine beating heart simulator for coronary artery bypass surgery residency training. J Thorac Cardiovasc Surg 2021;161(05):1878–1885

15 Ito J, Shimamoto T, Sakaguchi G, Komiya T. Impact of novel off-pump coronary artery bypass simulator on the surgical training. Gen Thorac Cardiovasc Surg 2013;61(05):270–273

