Multivessel minimally invasive on-pump direct coronary artery revascularization

Oleksandr Babliak^, Volodymyr Demianenko^, Anton Marchenko^, Dmytro Babliak^

Heart & Vascular Surgery Innovative Center at Dobrobut Medical Network, Kyiv, Ukraine

Contributions: (I) Conception and design: V Demianenko; (II) Administrative support: O Babliak; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: A Marchenko, D Babliak; (V) Data analysis and interpretation: V Demianenko, A Marchenko, D Babliak; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Oleksandr Babliak, PhD, MD; Volodymyr Demianenko, PhD, MD. Heart & Vascular Surgery Innovative Center at Dobrobut Medical Network, Kyiv, sim'i Idzikhovskyh, 3, 03151, Ukraine. Email: olexba@gmail.com; Vladimirsurgeon@gmail.com.

Background: Our aim was to describe the technique of minimally invasive on-pump multivessel coronary revascularization through the left anterior thoracotomy, evaluate the intraoperative and early postoperative results.

Methods: In this single-center retrospective cohort study we investigated the outcomes of 521 consecutive patients with isolated multivessel coronary artery disease (CAD) who were operated from July 2017 to December 2021. All operations performed via the left anterior minithoracotomy through the fourth intercostal space. Transthoracic clamp and blood cardioplegia were used for heart arrest and special maneuvers for coronary exposition. This technique was named total coronary revascularization via left anterior thoracotomy (TCRAT).

Results: The mean number of grafts was 2.97±0.7 [range, 2–5]. Left internal mammary artery (LIMA) was used in 494 (94.8%) patients, the right internal mammary artery (RIMA) in 10 (1.9%) patients, radial artery in 153 (29.4%) patients, and veins in 429 (82.3%) patients. In our series the mortality rate was 0.57% (3 cases), 2 (0.38%) conversions to sternotomy due to acute aortic dissection and no postoperative myocardial infarctions were observed. There were 2 (0.38%) postoperative strokes and 6 (1.15%) revisions for postoperative bleeding without conversion to sternotomy. The total operation time was 269±51.8 minutes, cardiopulmonary bypass time 145.7±33.5 minutes, and aortic cross-clamp time 71.9±19.9 minutes. The mean intensive care stay was 2.1±1.2 days and mean total hospital stay 5.9±2.2 days

Conclusions: The TCRAT technique could be used as a routine method of coronary artery bypass grafting (CABG) and provide the possibility to fully eliminate sternotomy for almost all patients (except porcelain aorta) with isolated multivessel CAD. Special surgical maneuvers for coronary targets exposure have made TCRAT more universal in practice than other minimally invasive CABG techniques. This technique preserves principles of complete coronary revascularisation and is applicable for multivessel CABG with use of standard coronary instruments and anastomotic techniques.

Keywords: Coronary artery bypass grafting (CABG); minimally invasive coronary artery bypass grafting; total arterial revascularization; total coronary revascularization via left anterior thoracotomy (TCRAT)

Received: 04 February 2022; Accepted: 01 November 2022; Published: 20 January 2023.

doi: 10.21037/jovs-22-2

View this article at: https://dx.doi.org/10.21037/jovs-22-2

^ ORCID: Oleksandr Babliak, 0000-0001-7698-1034; Volodymyr Demianenko, 0000-0002-5887-9949; Anton Marchenko, 0000-0001-8074-5165; Dmytro Babliak, 0000-0001-6119-4425.

Introduction

Minimally invasive multivessel coronary artery bypass grafting (CABG) is gaining more acceptance in the cardiac surgical society (1,2). Main minimally invasive CABG approaches had a list of disadvantages starting from surgery technique complicity, duration of procedures, expensive equipment requiring, long learning curve and patient selection (3-6).

Aiming for better patient's recovery in 2017 our team has developed new surgical maneuvers and techniques that has made a multivessel CABG through the left anterior minithoracotomy a routine procedure for isolated coronary artery disease (CAD) Our technique could be applied for the vast majority of patients regardless of the gender, age, body mass index (BMI), left ventricular ejection fraction (LVEF) and number, quality and location of diseased vessels (7). After 4 years of routinely performing minimally invasive multivessel total coronary revascularization via left anterior thoracotomy (TCRAT) we developed special technical details and safety tips of our technique that we want to describe in this paper. We present the following article in accordance with STROBE reporting checklist (available at https://jovs.amegroups.com/article/view/10.21037/jovs-22-2/rc).

Methods

In this single-center retrospective cohort study we investigated the outcomes of 556 consecutive patients with isolated CAD who were operated from July 2017 to December 2021. All surgeries, measurements and data collection were performed by authors team. Standard coronary surgery preoperative evaluation was performed for all patients. Additionally, we considered that computer tomography (CT) angiography must be the routine preoperative investigation. The operation technique, aortic cross-clamping and perfusion strategy were planned according to CT findings.

Patients who received multivessel revascularisation through median sternotomy [10 (1.8%)] or surgical revascularization by minimally invasive direct coronary artery bypass (MIDCAB) method (23, 4.1%) due to single vessel disease including only left anterior descending (LAD) artery involvement were excluded from the study. Patients who received multivessel surgical revascularization by method minimally invasive cardiac surgery (MICS) CABG (8) with "no touch aorta" technique (2, 0.3%) due to porcelain aorta were also excluded from the study.

In the rest 521 (93.7%) non-selected, consecutive patients we performed on-pump multivessel CABG via left anterior minithoracotomy according to TCRAT technique. We investigated main operative and early postoperative parameters among these patients. Main patient characteristics were shown in *Table 1*.

We had a few limitations to perform TCRAT:

- History of previous cardiac surgery.
- Circumferential aortic calcification (porcelain ascending aorta) at the site of aortic cross-clamping.

However, isolated atherosclerosis and calcification on the ascending aorta were not a contraindication for this procedure.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The Ethics Committee of the Heart & Vascular Surgery Innovative Center at Dobrobut Medical Network approved the protocol (approval number: 16), and all patients provided informed consent for usage of their medical data in this study.

Statistical analysis

Quantitative variables are presented as mean ± SD (minimum; maximum) or number (percentage) and calculated with use of Google Sheets (Google LLC) and MedCalcVR 16.8 (MedCalc Software bvba, Ostend, Belgium).

Surgical technique

The TCRAT technique contains multivessel revascularization through a left anterior minithoracotomy with peripheral cannulation for cardiopulmonary bypass (CPB) and aortic cross-clamping for cardioplegic arrest.

The main components of each surgical step that described below was shown in video attachment (*Video 1*).

Patients were placed in a supine position. An inflatable pad was located under the left side of the chest. The arms were positioned along the left chest. In cases where we used the radial artery as a coronary conduit, the left arm was left out at 90°.

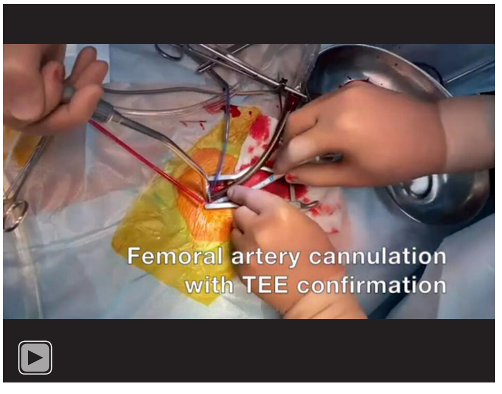
There were several additional steps performed preoperatively during anesthesia:

- We used 7–9 Fr Arndt bronchial blocker (Cook medical) for single-lung ventilation.
- To provide better venous blood drainage for

Table 1 Preoperative characteristics of the patients

Characteristics	Values (total patients, n=521)
Age, years	62.0±9.6 [31–86]
Male, n (%)	443 (85.0)
BMI, kg/m^2	30.1±4.5 [19.4–47.8]
LVEF, %	51.0±9.2 [15–70]
EuroScore II	1.06±0.66 [0.5–3.81]

Data are presented as mean ± SD [minimum–maximum] or number (percentage). BMI, body mass index; LVEF, left ventricular ejection fraction; SD, standard deviation.



Video 1 Step by step technique of total coronary revascularization via left anterior thoracotomy.

patients with the body surface area (BSA) ≥2.0 we cannulated the right jugular vein. For this purpose we administered 5,000 units of heparin and used arterial cannulas (DLP Femoral arterial cannula 17 or 19 Fr, Medtronic, Minneapolis, MN, USA).

- All patients received transesophageal echocardiography probe to provide safe peripheral cannulation.

Typically we performed peripheral cannulation of the right femoral artery and vein. We made a 2-cm incision in the groin and exposed anterior surfaces of the femoral vessels. After administration of a full dose of heparin [300 U/kg or to receive activated clotting time (ACT) more than 300 s] the vessels were cannulated. Due to preoperative CT data, in cases of severe atherosclerosis, we used alternative places for arterial cannulation (right axillary artery, left femoral artery). An arterial cannula, EOPA 18 to 20 Fr (Medtronic), or a Fem-Flex II Femoral cannula 16 Fr (Edwards Lifesciences, Irvine, CA, USA) were used for arterial inflow. Venous femoral cannula Bio-Medicus multi-stage 25 Fr or Bio-Medicus One-Piece 21 Fr (Medtronic) were used for venous return.

Thoracotomy was always performed through the 4th intercostal space. Skin incision with a length from 6 to 8 cm was performed just over the 4th rib for males and under the breast for women. To improve patients' recovery and reduce postoperative pain we performed muscle sparing thoracotomy during which pectoral muscle was split along its fibers. After the chest was opened, single-lung ventilation was initiated.

For thoracotomy, we use a retractor with blades 4 to 5 cm wide (Idol, Babliak Retractor or TSI, CT-0100: Pivoting Retractor or Delacroix-Chevalier, Sternal ThorAccess MIS Retractor) After retractor insertion, left internal mammary artery (LIMA) was detected. By this time, the full dose of heparin was administered and peripheral cannulation was performed. For LIMA harvesting we used special IMA retractor (Idol Babliak IMA Lifting System with Babliak IMA Upper Retractor Blade and Babliak IMA Lower RETRACTOR Blade or TSI, CT-1705: CT Lift System or Delacroix-Chevalier, MIDAccess IMA Retractor) and standard instruments with additional length (35-cm vascular forceps and pencils for electrocautery with 15-cm blade). The process of harvesting was started from clipping and dividing LIMA at the level of 4th intercostal space and continued with skeletonized technique beyond the origin of the left mammary vein.

We were usually started CPB at the end of LIMA harvesting. This maneuver improved the exposure of the proximal part of LIMA and added 5 to 10 minutes to on-pump time. In order to improve heart decompression we routinely used vacuum-assisted venous return during CPB.

The pericardium was opened longitudinally from the apex to the ascending aorta and to the sides. The ascending aorta was dissected and encircled with a tape. A transthoracic clamp (Idol, Babliak Aortic Clamp, DeBakey jaw, 230 mm working length) was introduced between the anterior axillary and midclavicular lines through the 2nd intercostal space. After aortic cross-clamping the cold blood cardioplegia was administered with repeat doses every 15–20 minutes.

Simultaneously, the radial artery and great saphenous vein were harvested. For endoscopic harvesting we used a reusable radial artery retractor system (Bisleri Model, Karl Storz, Tuttlingen, Germany) with an electrothermal bipolar vessel sealing device (Ligasure; Covidien, Boulder, CO, USA). To avoid twisting of the vein grafts at the time of construction of the proximal anastomosis one graft's side was marked with methylene blue.

In order to achieve the exposure of distal coronary targets several maneuvers were developed. These maneuvers required encircling of aorta, inferior vena cava (IVC) and both left pulmonary veins (LPVs) by the tapes. IVS and LPVs were encircled just after cardioplegia.

We started with right or circumflex coronary artery grafting and the last we did was LAD artery anastomosis.

For exposure of the inferior wall arteries we passed LPVs tape under the heart and pulled it cranially. IVC tape was pulled up. The other tapes were relaxed. For obtuse marginal arteries (OM) exposure we returned LPVs tape to the left side and pulled them up. IVC tape was passed under the heart to the left side and pulled up together with a heart. Finally, we performed an exposure of LAD territory. For this reason IVC tape was returned to the right. The anastomosis between LIMA and LAD was performed in side to side fashion. Diagonal branches were anastomosed sequentially by LIMA or separately by another graft. These exposure maneuvers give the opportunity to reduce average depth of coronary targets to the 6 cm (range, 4 to 9 cm) and as a result used standard coronary instruments and conventional anastomotic techniques.

As a second arterial conduit we used radial artery or right internal mammary artery (RIMA). These grafts were used for lateral and inferior wall targets with sequential or separate anastomoses technique. Proximal anastomoses were performed end to side to the aorta with using an aortic side-biting clamp or as T-shunt to LIMA. All T-shunts were performed during cardioplegia. In cases when second arterial grafts were not indicated we used saphenous vein grafts. A standard side-biting clamp was used to perform proximal saphenous vein anastomoses.

Single chest tube [BLAKE™ Silicone Drains (Round Hubless) 24 Fr] was inserted through the 2nd intercostal space at the place of transthoracic aortic clamp. Single polyester suture (B-Braun, Novosyn, USP 2) was used to approximate the ribs.

Results

From July 2017 to December 2021 we performed 533 multivessel CABG. Among these operations, 521 (97.7%) were performed by TCRAT technique, 2 (0.4%) by MICS CABG method and 10 (1.9%).

According to the last recommendation for coronary revascularization strategy (9) we used different conduits as bypass grafts. In all patients with LAD lesions LIMA was used—494 (94.8%) patients. Sequential LIMA anastomoses for diagonal branches of LAD were performed in 15 (2.8%) patients. For severe stenosis in main left circumflex (LCx) and right coronary artery (RCA) branches radial artery were used in 153 (29.4%) patients, and RIMA in 10 (1.9%) patients; 174 (33.4%) patients received 2 or more arterial distal anastomosis and 91 (17.4%) patients received total arterial revascularization. If arterial anastomoses were not appropriate or had bad quality we used saphenous vein grafts in 429 (82.3%) patients.

The aortic cross-clamp time was 71.9±19.9 (range, 31–133) minutes, CPB time was 145.7±33.5 (range, 71–236) minutes, and total operation time was 269.0±51.8 (range, 145–495) minutes. There were 3 (0.57%) cases of hospital or 30-day mortality, 2 (0.38%) conversions to sternotomy due to acute aortic dissection and no postoperative myocardial infarctions. The mean stay in the intensive care unit was 2.1±1.2 (range, 1–15) days. Postoperative strokes were diagnosed in 2 (0.38%) patients. Revisions for bleeding were performed in 6 (1.15%) cases without conversion to sternotomy. There were 9 (1.72%) cases of groin seroma. The mean total hospital stay was 5.9±2.2 (range, 3–30) days. Main operative and postoperative outcomes summarized in *Table 2*.

Discussion

The main idea of this paper is to show that special newly developed surgical maneuvers used in TCRAT and described in this paper have made TCRAT more universal in practice and different to the previously developed techniques of multivessel minimally invasive CABG [MICS CABG, totally endoscopic coronary artery bypass (TECAB), PortAccess CABG and Dresden approach] (2,4,8,10-13).

Basic distinguishing features of TCRAT include:

- Elimination of patient selection based on the coronary targets location and number, LVEF, urgency, patients gender and BMI;
- Peripheral CPB, cardioplegia and transthoracic clamp inserted laterally through the left chest;
- Coronary exposure maneuvers provided with the help of the tapes around the aorta, IVC and LPVs, which brings all coronary targets within 6 cm from the skin level.

Difficult surgery technique and additional equipment requirement were described as the one of the main problems of previously developed minimally invasive multivessel CABG techniques (8,10-13). These challenges have led

Table 2 Operative and postoperative characteristics

Characteristics	Values
Distal anastomoses/patient	2.97±0.68 [2–5]
LIMA, n patients (%)	494 (94.8)
Radial artery, n patients (%)	153 (29.4)
RIMA, n patients (%)	10 (1.9)
Veins, n patients (%)	429 (82.3)
Aortic cross-clamp time, min	71.9±19.9 [31–133]
CPB time, min	145.7±33.5 [71–236]
Total operation time, min	269±51.8 [145–495]
ICU stay, days	2.1±1.2 [1–15]
Total hospital stay, days	5.9±2.2 [3–30]
Conversion to sternotomy, n (%)	2 (0.38)
Revision for bleeding, n (%)	6 (1.15)
Stroke, n (%)	2 (0.38)
Groin seroma, n (%)	9 (1.72)
Hospital & 30 days mortality, n (%)	3 (0.57)

Data are presented as mean ± SD [minimum–maximum] or number (percentage). LIMA, left internal mammary artery; RIMA, right internal mammary artery; CPB, cardiopulmonary bypass; ICU, intensive care unit; SD, standard deviation.

to a high rate of patient selection, to special precautions, contraindications and to little spread of these techniques in the domain of coronary surgery (2).

In terms of technical complexity TCRAT is not significantly different from the conventional CABG as surgeons do anastomoses in the bloodless stable field, use usual length coronary instruments, can palpate arteries with fingers and don't require complex technologies. All these make the TCRAT a reproducible procedure, easy to start and with a short learning curve.

Safety of TCRAT is proved by our results (7) obtained from the series of consecutive patients starting from the first one, which represents 93.7% of patients presented to our hospital for isolated CABG. Regarding reproducibility, TCRAT have been successfully implemented in many countries around the world since our first international presentation in 2018 (14,15).

Below, we would like to draw the surgeon's attention to the important practical details of our method.

Firstly, it is extremely important to achieve full decompression of the heart on CPB and we should check this before cross clamping. If the heart is not empty, you have no space inside the chest to operate. For this reason in patients with BSA >2 m^2 we put a jugular vein before the incision.

Secondly, complete cross-clamping of the aorta should be confirmed immediately after clamp application. To verify this we apply suction on the aortic vent after cross-clamping and if the aorta doesn't collapse we should change the position of the clamp or change the transthoracic clamp.

Thirdly, we performed peripheral cannulation with administration of full dose of heparin (to receive ACT more than 300 s) parallel or even before thoracotomy and LIMA harvesting. The main reason is that we may start the CPB at any time we need, usually, during the harvesting of the proximal part of the LIMA. We didn't observe increased bleeding during thoracotomy or LIMA harvesting due to heparin administration.

Fourthly, we were always able to perform the complete coronary revascularization according to the preoperative plan. If a patient requires a multi-arterial grafting we prefer to use a radial artery as a second conduit. Mostly because of the technical difficulties in RIMA harvesting through the left anterior thoracotomy. Nevertheless, ongoing improvements in harvesting technologies will eliminate this technical drawback in the forthcoming years.

Finally, we always do a T-shunt during cardioplegia time, because the perfect exposure of T-shunt anastomosis can be obtained by pulling the LPVs tape. With a beating heart this maneuver is dangerous, as it will lead to pulmonary venous congestion.

Other safety issues include bleeding, proper graft measuring, and graft untwisting. These factors should be controlled during the CPB. Finally, it is necessary to feel comfortable in performing coronary anastomoses in a narrow wound (5 cm × 5 cm) with an average distance from skin to anastomosis near 6 cm.

With regard to limitations of this procedure, we should mention that in patients with porcelain ascending aorta we still may perform a minimally invasive CABG with a beating heart and "no-touch aorta" technique as it was already described by McGinn (8).

Conclusions

The TCRAT technique could be used as a routine method of CABG and provide the possibility to fully eliminate sternotomy for almost all patients (except porcelain aorta) with isolated multivessel CAD. Special surgical maneuvers for coronary targets exposure have made TCRAT more universal in practice than other minimally invasive CABG techniques. This technique preserves principles of complete coronary revascularisation and is applicable for multivessel CABG with use of standard coronary instruments and anastomotic techniques.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Johan van der Merwe and Filip P. Casselman) for the series "International Perspectives on Minimally Invasive Coronary Artery Revascularization" published in *Journal of Visualized Surgery*. The article has undergone external peer review.

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jovs.amegroups.com/article/view/10.21037/jovs-22-2/rc

Data Sharing Statement: Available at https://jovs.amegroups.com/article/view/10.21037/jovs-22-2/dss

Peer Review File: Available at https://jovs.amegroups.com/article/view/10.21037/jovs-22-2/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jovs.amegroups.com/article/view/10.21037/jovs-22-2/coif). The series "International Perspectives on Minimally Invasive Coronary Artery Revascularization" was commissioned by the editorial office without any funding or sponsorship. OB has consulted Idol Company and took part in designing and optimizing surgical instruments for TCRAT-CABG procedure. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The Ethics Committee of the Heart & Vascular Surgery Innovative Center at Dobrobut Medical Network approved the protocol (approval number: 16), and all patients provided informed consent for usage of their medical data in this study.

References

1. Van Praet KM, Kofler M, Shafti TZN, et al. Minimally Invasive Coronary Revascularisation Surgery: A Focused Review of the Available Literature. Interv Cardiol 2021;16:e08.
2. Bonatti J, Wallner S, Crailsheim I, et al. Minimally invasive and robotic coronary artery bypass grafting-a 25-year review. J Thorac Dis 2021;13:1922-44.
3. Liu JJ, Kong QY, You B, et al. Surgical Challenges in Multi-Vessel Minimally Invasive Coronary Artery Bypass Grafting. J Interv Cardiol 2021;2021:1195613.
4. Nambala S, Mishra YK, Ruel M. Less invasive multivessel coronary artery bypass grafting: now is the time. Curr Opin Cardiol 2021;36:735-9.
5. Torregrossa G, Sá MP, Van den Eynde J, et al. Robotic hybrid coronary revascularization versus conventional off-pump coronary bypass surgery in women with two-vessel disease. J Card Surg 2022;37:501-11.
6. Sakaguchi T, Totsugawa T, Tamura K, et al. Minimally invasive coronary artery bypass grafting: useful routine option for coronary revascularization in selected cases. Gen Thorac Cardiovasc Surg 2020;68:1128-33.
7. Babliak O, Demianenko V, Melnyk Y, et al. Complete Coronary Revascularization via Left Anterior Thoracotomy. Innovations (Phila) 2019;14:330-41.
8. McGinn JT Jr, Usman S, Lapierre H, et al. Minimally invasive coronary artery bypass grafting: dual-center experience in 450 consecutive patients. Circulation 2009;120:S78-84.
9. Lawton JS, Tamis-Holland JE, Bangalore S, et al. 2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization: Executive Summary: A Report of the American College of Cardiology/American Heart

Association Joint Committee on Clinical Practice Guidelines. Circulation 2022;145:e4-e17.
10. Gulielmos V, Brandt M, Knaut M, et al. The Dresden approach for complete multivessel revascularization. Ann Thorac Surg 1999;68:1502-5.
11. Nambiar P, Mittal C. Minimally invasive coronary bypass using internal thoracic arteries via a left minithoracotomy: "the Nambiar Technique". Innovations (Phila) 2013;8:420-6.
12. Yilmaz A, Robic B, Starinieri P, et al. A new viewpoint on endoscopic CABG: technique description and clinical experience. J Cardiol 2020;75:614-20.
13. Narayan P, Angelini GD. Robotically assisted hybrid coronary revascularization-Masterly technique but is it for the masses? J Card Surg 2022;37:906-8.
14. Çaynak B, Sicim H. Routine minimally invasive approach via left anterior mini-thoracotomy in multivessel coronary revascularization. J Card Surg 2022;37:769-76.
15. Erdogan E, Gokarslan G, Uygur F, et al. Postoperative Early Outcomes of Conventional versus Minimally Invasive Multivessel Coronary Artery Bypass Surgery: Retrospective Study. Ukrainian Journal of Cardiovascular Surgery. Professional Edition Eastern Europe 2021;4:30-5.

doi: 10.21037/jovs-22-2
Cite this article as: Babliak O, Demianenko V, Marchenko A, Babliak D. Multivessel minimally invasive on-pump direct coronary artery revascularization. J Vis Surg 2023;9:2.

