Original Article
Cukurova Anestezi ve Cerrahi Bilimler Dergisi

Classical or minimally invasive coronary revascularization surgery? What's the difference?

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Abstract

Aim: The aim of coronary bypass surgery is complete revascularization. As a current method that provides this and minimizes patient choice, we aimed to report the classic CABG (Coronary Artery Bypass Graft surgery) series performed by the same team during the same period with the TCRAT (Total Coronary Revascularization via Small Left Anterior Thoracotomy) method by comparing it with in-hospital and 30-day results.

Methods: This study included 250 patients with multivascular lesions who underwent total coronary revascularization with the TCRAT method between January 2020 and January 2024, and 250 patients who underwent conventional CABG by the same team during the same period. All patients underwent surgery using standard surgical instruments, and all underwent two or more distal anastomoses.

Results: In the operative data, CPB (Cardio Pulmonary Bypass) time was 68.3±15.7 minutes and cross-clamp time was 34±10.6 minutes in the CABG group, while in the TCRAT group, CPB time was 102.8±23.3 minutes and cross-clamp time was 63.7±23.3 minutes. ($p<0.001$). The postoperative blood transfusion requirement during the intensive care period was 2±0.6 units in the CABG group and 0.8±0.4 units in the TCRAT group ($p<0.001$). The extubation time for patients in the intensive care unit was 11±1.6 hours in the CABG group and 6.5±1 hours in the TCRAT group ($p=0.001$). New postoperative AF development was observed in 45 (18%) patients in the CABG group, compared to 22 (8.8%) in the TCRAT group ($p=0.003$). The revision rate, including suture and debridement, was limited to 75 (30%) patients in the CABG group and 5 (2%) in the TCRAT group ($p<0.001$).

Conclusions: When the likelihood of delayed wound and bone healing and return to daily life increases with conventional CABG, the TCRAT technique can be considered as an alternative surgical method.

Keywords: *Minimally invasive cardiac surgery; coronary artery bypass grafting; revascularization; left anterior thoracotomy*

1. Introduction

The profile of cases requiring coronary revascularization surgery has changed dramatically over the years. Both the increase in life expectancy, technological and pharmacological developments and the change in contemporary methods in interventional approaches to complex cases have allowed surgical treatment decisions to be postponed for a long time. With the influence of these factors, we are witnessing the patients for whom surgical treatment is decided to be transformed into more complex cases than in the past. However, there have been studies for a long time to minimize surgical revascularization methods, and we are also researching ways to make minimally invasive methods easier for more complex cases. When we evaluate the patient profiles for whom surgical revascularization is decided today, it is often observed that they have a history of more than one interventional cardiological procedure, and that the coronary vascular bed is affected by the current disease and sometimes by the procedures. Multiple terminal organ or system dysfunctions are also frequently observed. There have been no major changes in the basic principles of coronary revascularization indications. These principles are to restore impaired myocardial perfusion, to keep the tissue trauma associated with the treatment method at the lowest level, to ensure long-lasting revascularization and to be cost-effective at the same time. In cases with low ejection fraction, diabetes and complex multivessel stenoses, the basic standard method is surgical revascularization. However, aesthetic concerns along with the recovery time and return to normal life in patients undergoing revascularization with median sternotomy increase the demand for less invasive methods.[1,2,3]

The TCRAT (Total Coronary Revascularization via left Anterior Thoracotomy) method has been presented as an alternative to classical CABG (Coronary Artery Bypass Graft) surgery in terms of enabling complete revascularization, minimizing surgical trauma and faster postoperative recovery.[4] We have included this minimally invasive technique (TCRAT) in our routine surgical protocols since 2020. We compared TCRAT and Classic CABG cases performed by

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the same team in the same time period, along with their technical details. We tried to evaluate the strengths and weaknesses of both methods. This report includes the early comparative results of both methods.

2. Materials and Methods

This report was designed as a retrospective cohort study including 250 patients who underwent complete revascularization via TCRAT and 250 patients who underwent classical CABG between January 2020 and January 2024. All cases were performed by the same surgical team at Sanko University Hospital, and this study was performed with the permission of Sanko University Clinical Research Ethics Committee coded KAEK-018-1 and the guidelines set out by the Declaration of Helsinki were followed. The inclusion criteria for the study were TCRAT surgery cases with two or more distal anastomoses performed in conjunction with extra-corporeal circulation.

Exclusion criteria were minimally invasive coronary revascularization surgery cases performed by methods other than extra-corporeal circulation, minimally invasive valve or congenital heart disease surgery cases, incomplete revascularization or hybrid surgery cases, single vessel bypass cases, advanced peripheral arterial disease, left subclavian artery occlusion, redo and combined surgery, emergency surgery and undergone left thoracotomy or breast surgery. All patients underwent computed tomography in addition to the standard institutional preoperative examinations to screen the ascending aorta, the aortic arch, and major arterial branches, especially the iliac and femoral arteries, for atherosclerotic disease and anatomical abnormalities. At the same time, whether there was any pathology related to the venous system was also evaluated.

Surgical Technique

The patients were placed in a supine position, with a 30 ∘ elevation of the left hemithorax. They were intubated with a Carlens endotracheal tube to deflate the left lung. Central venous and arterial catheterization was performed. A left anterior mini thoracotomy was performed with an approximately 6 cm incision, and the thoracic cavity was reached through the 4th intercostal space.(Figure 1)

Figure 1

Left anterior mini thoracotomy

The left lung was deflated. The LIMA(Left Internal Mammarian Artery) was prepared in a skeletonized manner using a specially designed LIMA retractor (Lifting retractor, Geister, Tuttlingen, Germany). The GSV(Great Saphenous Vein) was removed endoscopically simultaneously. During this time, the patient was given heparin at a dose of 3 mg/kg. The femoral artery and vein were accessed through an approximately 4 cm infrainguinal incision. The artery and vein were suspended with tape and cannulation was performed by placing purse string sutures. LIMA proximal and distal preparation was completed under CPB (Cardio Pulmonary Bypass). Subsequently, a pericardiotomy was performed and suspending sutures were placed. The ascending aorta was returned through the aorticopulmonary window and suspended with nylon tape. To support the position of the heart, a mini incision was made from the midaxillary line 5th intercostal space and the over-clamp was advanced from the thorax into the pericardium and a gause was prepared by mounting it on the tip. A mini incision was made from the anterior axillary line 2nd intercostal space and Chitwood DeBakey Clamp (Scanlan® International Inc. Saint Paul, Minnesota, USA) was placed. Diastolic arrest was achieved with antegrade isothermic blood cardioplegia under mild hypothermia of 32 º. Vacuum-assisted venous return was routinely used during CPB to improve heart decompression. (Figure 2).

Figure 2

Intraoperative image

After the distal anastomoses were performed, the proximal anastomoses were performed with the single clamp technique. While performing the last proximal anastomosis, warming was started. After the proximal anastomoses, the cross clamp was removed by giving hot blood cardioplegia. The heart was defibrillated in necessary cases. After leaving the CPB, heparin was neutralized with 1:1 protamine sulfate. A drain was placed in the thorax through the incision in the 5th intercostal space. After hemostasis, the surgical incision was closed by performing an intercostal block with 2% marcaine. The patients were taken to the ICU(Intensive Care Unit) while intubated.

All of the cases were operated with standard surgical instruments. LivaNova (Sorin Group Italia S.r.l. Strada Statale 12 Nord, 86 Mirandola (MO) 41037 Italy) brand cannulas of appropriate sizes were used for femoral artery, vein and cardioplegia. During the surgery, the heart was positioned using suspension sutures for the distal anastomoses, a thoracic over-clamp with mounted gauses. Proximal anastomoses were performed by deviating the aorta to the left with the single clamp technique and applying PEEP(Positive End Expiratory Pressure) to the right lung.

Classical CABG cases were performed by the same surgical team using the classical median sternotomy method and standard instruments.

Postoperative care and clinical follow-up included documentation of hemodynamic parameters, wound healing and possible postoperative complications such as infections or bleeding.

Statistical Analysis

IBM SPSS Statistics 23 package program was used for data analysis. Descriptive statistics were given as mean and standard deviation or median and minimum-maximum values for quantitative variables, and frequency and percentage values for qualitative variables. The normality of distribution of quantitative variables was evaluated with the Kolmogorov-Smirnov test. In comparisons of two independent groups in terms of quantitative variables, if the conditions for parametric tests were met, independent samples t-test was used, and if the conditions for parametric tests were not met, Mann-Whitney U test was used. In comparisons of more than two independent groups in terms of quantitative variables, one-way ANOVA was used if the conditions for parametric tests were met, and the Kruskal-Wallis test was used when the conditions for parametric tests were not met. The relationship between two continuous variables was evaluated with Pearson or Spearman Rank correlation coefficients. For group comparisons of qualitative variables, the chi-square test was used and $p<0.05$ was considered statistically significant.

3. Results

All of the cases were patients who underwent multiple distal anastomoses. Hemodynamic parameters, wound healing, peroperative and postoperative complications like infections or bleeding were documented. Patients who developed complications outside of the routine follow-up program were monitored by phone or by inviting them to the hospital.

The mean age of the patients who underwent CABG was 61.9±9.8 years, 70 patients were women, 180 patients were men, EuroSCORE 2 (European System for Cardiac Operative Risk Evaluation) was 2.63±0.91, EF (Ejection Fraction) was 54.4±7.4, BMI (Body Mass Index) was 29.2±4.6. The DM (Diabetes Mellitus) rate was 33.2% (83 patients) in this group. The average age of the group who underwent TCRAT was 60.8±10.1 years, 57 of them were women, 193 of them were men, EuroSCORE 2 was 2.65±1.06, EF was 54.4±7.8, BMI was 29±4.3.

Table 1

Preoperative variables

Variables	CABG Mean±SD	TCRAT Mean±SD	p
Age	61,9±9,8	60,8±10,1	0,221
Sex(male)	180 (72%)	193 (77,2)	0,182
DM	83 (33,2)	96 (38,4)	0,225
EuroSCORE 2	2,63±0,91	2,65±1,06	0,773
EF	54,4±7,4	54,4±7,8	0,776
BMI	29,2±4,6	29±4,3	0,390

DM: *Diabetes Mellitus, EF: Ejection Fraction, BMI: Body Mass Index, EuroSCORE: European System for Cardiac Operative Risk Evaluation*

The diabetes rate in this group was 38.4 %(96 patients). There was no statistically significant difference between the patient groups in terms of age, gender, EuroSCORE 2, BMI, EF and DM incidence rate. In both groups, the majority of the patients had 3 or more vascular diseases. LIMA and GSV were prepared in all of them. GSV preparation was performed endoscopically in all patients. Complete anatomical revascularization was achieved 100 %. Preoperative characteristics of the patients are shown in table 1.

Table 2

Operative and ICU variables

Variables	CABG (n=250)		TCRAT (n=250)		P
	Mean±SD	Median (Q1-Q3)	Mean±SD	Median (Q1-Q3)	
CPB time(m)	68,3±15,7	69,5 (55-80)	102,8±23,3	102 (88-120)	<0,001
Cross klemp time(m)	34±10,6	35 (24-41)	63,7±23,3	62 (44-85)	<0,001
Distal Anastomosis	3,7±0,9	4 (3-4)	3,4±0,7	3 (3-4)	<0,001
Transfusion	2±0,6	2 (2-2)	0,8±0,4	1 (1-1)	<0,001
Extubation time(h)	11±1,6	11 (10-12)	6,5±1	6 (6-6)	<0,001
ICU(h)	37,3±3,8	36 (36-36)	38,1±6,2	36 (36-36)	0,933
Patient Room(h)	102,6±10,7	96 (96-120)	100,7±10,3	96 (96-96)	0,033
Hb	10,2±0,6	10 (10-10)	10,5±0,7	10 (10-11)	<0,001
WBC	11,1±1,6	11 (10-12)	10,2±1,7	10 (9-12)	<0,001

When we looked at the operative data, CPB time was 68.3±15.7 minutes in the CABG group, cross-clamp time was 34±10.6 minutes, while CPB time was 102.8±23.3 minutes in the TCRAT group and cross-clamp time was 63.7±23.3 minutes, and these periods were significantly longer in the TCRAT group ($p< 0.001$).The average number of distal anastomoses performed was 3.7±0.9 in the CABG group, while it was 3.4±0.7 in the TCRAT group, and it was noticeable that the number of anastomoses was lower in the TCRAT group ($p<0.001$). The operational variables are shown in table 2.

When we examined the data in the intensive care follow-up, the need for blood transfusion during the post-operative intensive care period was 2±0.6 units in the CABG group and 0.8±0.4 units in the TCRAT group ($p<0.001$). The extubation time of the patients in the intensive care unit was 11±1.6 hours in the CABG group and 6.5±1 hour in the TCRAT group ($p<0.001$). The average length of stay in the patient room was 102.6±10.7 hours in the CABG group and 100.7±10.3 hours in the TCRAT group($p=0.033$).

Table 3

Postoperative Adverse Situations

Variables		CABG Number (%)	TCRAT Number (%)	p
Infection	No	242 (96,8)	247 (98,8)	0,127
	Yes	8 (3,2)	3 (1,2)	
Drainage	No	203 (81,2)	238 (95,2)	<0,001*
	Yes	47 (18,8)	12 (4,8)	
Necrosis	No	219 (87,6)	250 (100)	<0,001*
	Yes	31 (12,4)	0 (0)	
Dehiscence	No	178 (71,2)	244 (97,6)	<0,001*
	Yes	72 (28,8)	6 (2,4)	
Revision	No	175 (70)	245 (98)	<0,001*
	Yes	75 (30)	5 (2)	
Hospital Mortality	No	250 (100)	249 (99,6)	1,000
	Yes	0 (0)	1 (0,4)	
30 Day Mortality	No	244 (97,6)	245 (98)	0,760
	Yes	6 (2,4)	5 (2)	
Athelectasia	No	221 (88,4)	214 (85,6)	0,352
	Yes	29 (11,6)	36 (14,4)	
Stroke	No	247 (98,8)	249 (99,6)	0,623
	Yes	3 (1,2)	1 (0,4)	
AF	No	205 (82)	228 (91,2)	0,003*
	Yes	45 (18)	22 (8,8)	
ATN	No	248 (99,2)	249 (99,6)	1,000
	Yes	2 (0,8)	1 (0,4)	
Tamponade	No	247 (98,8)	250 (100)	0,248
	Yes	3 (1,2)	0 (0)	

**p<0,05: Chi-square test, AF: Atrial Fibrillation, ATN: Acute tubuler necrosis*

Among the hemogram parameters examined during the end of intensive care follow-up, the Hb (Hemoglobin) value was found to be 10.2±0.6 in the CABG group, and 10.5±0.7 in the TCRAT group($p<0.001$), while the WBC (White Blood Count) value was found to be 11.1±1.6 in the CABG group and 10.2±1.7 in the TCRAT group($p<0.001$). ICU data are given in Table 2.

There was no significant difference between the two groups in terms of infection, atelectasis, stroke, ATN, cardiac tamponade, hospital mortality and 30-day mortality that occurred in the postoperative period. New AF development after surgery was seen in 45 (18%) patients in the CABG group, while in the TCRAT group this number was 22 (8.8%) patients ($p<0.001$). Discharge at the wound site was seen in 47 (18.8%) patients in the CABG group and in 12 (4.8%) patients in the TCRAT group($p<0.001$). Skin necrosis was seen in 31 (12.4%) patients in the CABG group, while it was seen in 0 (0%) patients in the TCRAT group. The incidence of wound dehiscence was 72 (28.8%) patients in the CABG group and 6 (2.4%) patients in the TCRAT group. The revision rate, including suture and debridement, was limited to 75 (30%) patients in the CABG group, while it was 5 (2%) patients in the TCRAT group. One of the factors affecting wound dehiscence and revision is the saphenectomy incision together with the chest incision, and while endoscopic saphenous preparation was performed in all patients in the TCRAT group, the open saphenectomy method was used in the CABG group. Postoperative adverse events and outcomes are given in Table 3.

4. Discussion

Over the years, research has been conducted in all surgical branches to minimize incisions for faster wound healing, protection from infection and aesthetic concerns, and minimally invasive surgical techniques have gained popularity in all surgical fields. In cardiac surgery, surgical methods with small incisions have been studied since the 90s. It was first published in 1996 by Calafiore et al. a series of surgical revascularization performed with minimal incision has been published by. In the following years, robotic-assisted or hybrid approaches have emerged for access to other coronary targets.[5,6] Although robotic or endoscopic-assisted CABG significantly reduces the invasiveness of the operation, this technique has only been performed in a small number of specialized centers, in selected patients.[7,8] Similarly, minimally invasive cardiac surgery MICS(Minimally Invasive Cardiac Surgery)OPCABG(Off Pump Coronary Artery Bypass Grafting) has been introduced to enable revascularization in multi-vessel disease through a small lateral thoracic incision by combining special retractors, special cardiac apical positioners and special epicardial stabilizers. Again, only a few groups worldwide have routinely adopted this technically challenging procedure, and MICS OPCAB has been performed in only a very small number of patients so far.[9,8]

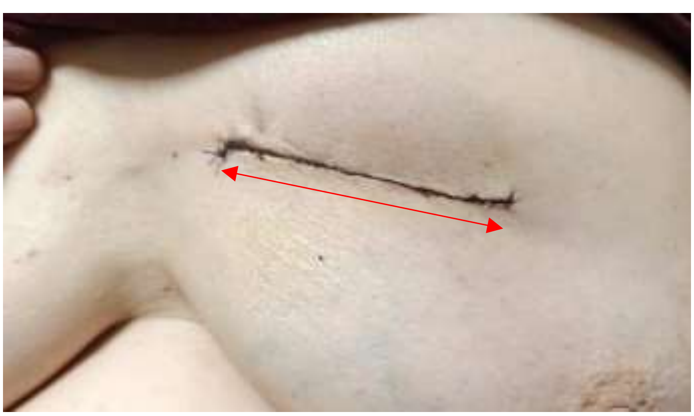
Because the MIDCABG(Minimally Invasive Direct Coronary Artery Bypass Grafting) , MISC-OPCABG(Off-Pump Coronary Artery Bypass), RACABG(Robotic-Assisted Coronary Artery Bypass Grafting) and TECABG (Totally Endoscopic Coronary Artery Bypass Grafting) techniques fail to provide sufficient complete revascularization, HCR(Hybrid Coronary Revascularization), which involves stenting coronary arteries that cannot be surgically revascularized, has been proposed as an alternative, but this has not achieved the desired results. Finally, as an alternative to MIDCABG, MISC-OPCABG, TECABG, and HCR which have long had limited application, Babliak et al. described the TCRAT method, which allows complete revascularization under routine operating room conditions and with routine surgical instruments. This method remains the most current approach.[4] The aim of the operation performed with the TCRAT method is to allow a revascularization equivalent to a classical CABG operation, with high surgical precision and safety, through a minimal surgical opening. Because the gold standard in surgical revascularization is the grafting of all coronary arteries with a diameter exceeding 1.5 mm and a lumen stenosis by 50% or more in patients with multivessel disease.[6] (Neumann et al., 2019) Therefore, the number of grafts performed in surgical revascularization is often considered the most important parameter for complete revascularization in patients with multivessel disease.[10]

We have also started to routinely perform the TCRAT method in minimally invasive coronary revascularization surgery since 2020. When we looked at the preoperative variables of the cases in the study protocol, we observed that the age, gender distribution, Diabetes Mellitus, EuroSCORE 2, EF and BMI averages were similar in both groups and there was no statistical difference. Preoperative variables are given in table 1.

When we evaluated the operative data, it was observed that CPB and cross clamp time were significantly shorter in the CABG group than in the TCRAT group. One of the reasons for this was that the small incision caused difficulty in manipulations and anastomosis, while the other reason was that the proximal anastomoses in the TCRAT group were performed with the single clamp technique. In the case series of Babliak et al., the operative time variables are also observed to be similar.[4] The average distal anastomosis performed was 3.7±0.9 in the CABG group and 3.4±0.7 in the TCRAT group. We also associated this with the fact that we treated patients who had a common peripheral artery disease and were not suitable for TCRAT by performing classical CABG surgery. We evaluated it as a result of the fact that the number of coronary target vessels is also higher in cases with diffuse atherosclerotic disease, which is not particularly suitable for peripheral cannulation.

Figure 3

Postoperative fifth day



Arrow length 6.0 cm

When we consider the data related to the intensive care process, the average transfusion need at the end of this process was 2±0.6 in the CABG group, while it was 0.8±0.4 in the TCRAT group. We have witnessed that the need for transfusion has decreased significantly due to the smaller incision and more controlled manipulations. We would like to state that this is in line with the literature and that the need for transfusion in minimally invasive surgery is lower than in classical surgery. Similarly, the mechanical ventilation time was 11±1.6 hours in the CABG group, while it was 6.5±1 hour in the TCRAT group, and the mechanical ventilation time was lower in the TCRAT group.[11,12] At the end of the intensive care period, the average blood values were Hb 10.2±0.6, WBC 11.1±1.6 in the CABG group, while Hb 10.5±0.7, WBC 10.2±1.7 in the TCRAT group. There was no significant difference in the duration of service follow-up during the postoperative period. When we looked at the hospitalization process and early postoperative follow-up, we observed that the incidence of discharge, necrosis, and dehiscence at the wound site was less in the TCRAT group(Figure 3).

In parallel with this situation, the surgical revision rate was also observed to be lower in the TCRAT group. We evaluated that these findings were related to the incision size. These results were also consistent with the literature. However, no difference was detected in the frequency of wound infection.[13,4, 14] The development of postoperative AF is an important complication among undesirable events in cardiac surgery, and is an event that we encounter quite frequently and requires real-time treatment. The development of postoperative AF was also observed to be lower in the TCRAT group, and we thought that this was related to both the strict follow-up of postoperative pain control, early separation from mechanical ventilation and the earlier return of respiratory functions to normal.[9,15] The advantage of minimally invasive coronary artery revascularization is likely to be more pronounced in patients with uncontrolled diabetes or multiple comorbidities that increase the risk of sternum wound healing, dehiscence and infection. Moreover, if a mini-thoracotomy is performed, there is no need for bone healing after surgery and patients can return to their normal lives more quickly. Thanks to smaller incisions, patients can be extubated more quickly and respiratory failure complications are less common. Also patients can be removed from intubation more quickly and respiratory failure complications are less common. In the prospective study reported by Diegeler et al., they claimed that MIDCABG caused less pain than classical CABG.[11] In our cases, although the total hospitalization period is similar to classical surgery, the pain duration and the return to daily life are significantly shorter.[11,12,16] Contrary to the literature, in terms of intensive care and total hospital stay, our study showed that the TCRAT group and the classical CABG group were similar.[17,18] When we examine the literature data on shorter hospital stay, it usually stands out that the target vessel is only LAD (Left Anterior Descending) and off-pump surgery is performed. In series where complete revascularization is performed like ours, this period progresses similarly to classical surgery.[7,19] We observed no significant difference between the groups in terms of hospital mortality, 30-day mortality, atelectasis, stroke, ATN and tamponade development. Although it is thought that aortic manipulation and CPB, especially subclavian or axillary artery cannulation, may be associated with an increase in stroke rate, stroke developed in only two cases (0.8%) in our series. This is a rate similar to that of classical bypass cases.[20] Wound infection was observed at a rate of 1.2%, serous drainage at a rate of 4.8%, and was within acceptable limits, while hematoma development at the thoracotomy incision site was detected at a rate of 6%. The condition that triggered the development of hematoma is related to the separation of pectoral muscle fibrils, and surgical wound revision was required in only 3 patients (1.2%). Hematoma development at the surgical site has not been found much in the literature review, and it has not been possible for us to compare this result. In 6 patients, debridement and re-suturing were performed due to wound dehiscence, but necrosis was not encountered in the wound area. The rate of re-thoracotomy due to bleeding occurred in 2(0.8%) patients, which is consistent with the literature.[21] A postoperative acute renal failure requiring hemodialysis was observed in one patient (0.4%), which is lower than the literature. We thought that the reason for this was that combined and emergency surgeries were not included in the study.[13]

Finally, our rate of return to sternotomy occurred in only one case (0.4%). The reason for this was the injury to the right pulmonary artery.

Limitations of the study

Despite the promising results of our study, we are aware of some limitations. The study design is retrospective and observational, and the limited number of cases and follow-up period are the flaws of this study. A longer follow-up period and a sufficient number of cases would be ideal for a more accurate evaluation of the TCRAT technique. It is also important to note that one of the factors that led to these results is the experience level of the surgical team and the number of procedures they have performed, which may have affected the results. The inclusion criteria for the study also have a major impact on the results, and we hope that future studies will reduce the question marks.

5. Conclusions

We think that coronary revascularization surgery performed by experienced teams with the TCRAT technique may be an advantageous technique in cases with high morbidity risk. It may provide better results than classical surgery in patients with advanced age or multiple comorbidities, as well as a high risk of wound and bone healing. Careful evaluation of the risk profile of patients and full identification of their suitability for preoperative minimally invasive surgery can directly affect the results. In addition, there are confusing differences in the names used for minimally invasive coronary surgery. Therefore, clarifying the nomenclature issue with a consensus will prevent terminological chaos.

Statement of ethics

The study received ethical approval the Sanko University Clinical Research Ethics Committee coded KAEK-018-1 and the guidelines set out by the Declaration of Helsinki were followed.

genAI

No artificial intelligence-based tools or generative AI technologies were used in this study. The entire content of the manuscript was originally prepared, reviewed, and approved by both authors.

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Conflict of interest statement

The authors declare that they have no conflict of interest.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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