J Updates Cardiovasc Med 2025;13(4):177-185 **DOI:** 10.32596/jucvm.galenos.2025-2025-18-162

Peripheral Cannulation vs. Conventional Methods in Redo Cardiac Surgery: A Single-Center Experience

Hasan Toz, Yusuf Kuserli, Onur Emre Satılmış, Gülsüm Türkyılmaz, Saygın Türkyılmaz, Ali Aycan Kavala

University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinic of Cardiovascular Surgery, İstanbul, Türkiye

Abstract

Objectives: This study aims to compare the outcomes of peripheral cannulation (PC) and central cannulation (CC) techniques in redo cardiac surgeries.

Materials and Methods: A retrospective analysis was conducted on 104 patients who underwent redo cardiac surgery between January 2010 and January 2023. Patients were divided into two groups based on the cannulation technique used: PC (n=56) and CC (n=48). Preoperative, intraoperative, and postoperative parameters were collected and analyzed.

Results: Significant differences were observed in cardiopulmonary bypass time (127.1±13.6 minutes for PC vs. 120.1±15.4 minutes for CC, p=0.021) and total operation time (295.7±40.4 minutes for PC vs. 249.9±39.5 minutes for CC, p<0.001). The incidence of procedure-related injuries was significantly lower in the PC group (5.4% vs. 31.2%, p=0.036). Overall complications were also significantly lower in the PC group (10.7% vs. 35.4%, p<0.001). Postoperative ventilation duration was shorter in the PC group (5.4±1.1 hours vs. 6.0±1.5 hours, p=0.036). Hemoglobin, C-reactive protein, and ejection fraction levels pre- and postoperatively showed no significant differences between the groups. These findings suggest that PC may offer a safer alternative with fewer complications in redo cardiac surgeries.

Conclusion: PC may offer a safer alternative with fewer complications in redo cardiac surgeries compared to CC. These findings suggest the potential benefits of using PC in reducing procedure-related injuries and overall complications.

Keywords: Cardiopulmonary bypass, central cannulation, peripheral cannulation, redo surgery, surgical complications

Address for Correspondence: Hasan Toz, University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinic of Cardiovascular Surgery, İstanbul, Türkiye
e-mail: tozhasan@hotmail.com **ORCID:** orcid.org/0000-0002-4228-6233
Received: 11.03.2025 **Accepted:** 25.11.2025 **Publication Date:** 12.12.2025

Cite this article as: Toz H, Kuserli Y, Satılmış OE, et al. Peripheral cannulation vs. conventional methods in redo cardiac surgery: a single-center experience. J Updates Cardiovasc Med. 2025;13(4):177-185.

DOI: 10.32596/jucvm.galenos.2025-2025-18-162

Introduction

Cardiac reoperations pose significant challenges, necessitating specialized strategies and meticulous precautions to mitigate complications throughout the surgical process. During resternotomy and pericardial dissection, there is a risk of catastrophic outcomes due to potential injury to the right ventricle, reduction in great artery pressure, and damage to the patent bypass graft. Although no definitive method exists to completely prevent complications and mortality, ongoing efforts and discussions have persisted for years[1,2].

Although various studies highlight the benefits of peripheral cannulation (PC)[3,4], there is also research indicating that routine use of PC may be unnecessary, as standard central cannulation (CC) yields favorable outcomes[3]. The aim of this study is to evaluate the efficacy and safety of PC compared to conventional CC in patients undergoing redo cardiac surgery. By analyzing outcomes such as complication rates, procedural success, and overall patient prognosis, we seek to determine whether PC offers significant advantages or if CC remains the optimal approach in these complex surgical cases.

In recent years, the increasing number of patients requiring repeat cardiac surgeries due to improved long-term survival has intensified the focus on optimizing reoperative strategies[5,6]. The complex anatomical changes and adhesions that develop following initial procedures complicate re-entry and surgical exposure, thereby increasing the risk of life-threatening intraoperative events. Consequently, determining the most effective and safest cannulation technique has become a matter of considerable clinical interest, as it can directly influence operative safety, morbidity, and overall patient outcomes[7,8].

Therefore, the objective of this study is to conduct a comprehensive comparison between peripheral and CC techniques in the context of redo cardiac surgery. By systematically evaluating perioperative complications, mortality, and recovery parameters in a contemporary patient cohort, we aim to provide robust scientific evidence that will inform surgical decision-making and potentially improve the standard of care for this high-risk population.

Materials and Methods

Study Design

This retrospective study was approved by the Ethics Committee of tertiary University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital (approval no: 2024-04-05, date: 04.03.2024). The study involved patients undergoing redo cardiac surgery between January 2010 and January 2023.

Patient Selection

The study included a total of 104 patients who underwent redo cardiac surgery using either PC (n=56) or CC (n=48) techniques. Surgeries performed at least 30 days after the initial cardiac operation were excluded from the study. Patients undergoing PC with no suitable femoral artery cannulation site, those with chronic deep vein thrombosis, and those with Leriche syndrome were also excluded. In the early years (2010-2015), CC was predominantly used, whereas in the later years (2016-2024), PC became more common. The surgical team performing the redo surgeries remained the same throughout the study period. Patients were classified according to the initial site of arterial and venous access used for cardiopulmonary bypass (CPB) initiation. In the PC group, the femoral artery and vein (with additional internal jugular venous cannulation when necessary) were cannulated before sternotomy. In the CC group, CPB was initiated via the ascending aorta and right atrium after sternotomy.

Data Collection

Data were collected on demographic characteristics (age, gender, smoking status, hypertension), anthropometric measurements [height, weight, body mass index (BMI)], preoperative and postoperative hemoglobin (Hb) levels, operative variables [temporary and permanent pacemaker insertion, chest drainage amount, blood product usage, bleeding revision, ventilation time, intensive care

unit (ICU) stay, hospital stay, hospital mortality, and complications]. The collected data were transferred to a digital database for analysis.

Cannulation Techniques

Central Cannulation

Following anesthesia preparation, the patient was draped in a sterile manner, and a sternotomy was performed. The old sternal wires were excised and removed, and a redo sternotomy was executed using a specialized saw. Adhesions were carefully bluntly dissected to expose the ascending aorta and right atrium. After systemic heparinization, an aortic cannula was inserted into the ascending aorta, and a venous cannula was placed in the right atrium. Subsequently, CPB was initiated.

Peripheral Cannulation

Anesthesia typically included the placement of a 7F sheath in the right internal jugular vein under ultrasound guidance to minimize intraoperative handling. A central venous catheter was also inserted into the left internal jugular vein. The patient was then draped in a sterile manner, and the femoral vein and artery were assessed via ultrasound for thrombus, stenosis, and calcifications. Given its proximity to the primary surgeon, the right femoral artery and vein were explored and prepared. Systemic heparinization was administered. Utilizing the Seldinger technique, a guidewire was initially inserted into the femoral artery, followed by the placement of the arterial cannula. A guidewire was then advanced through the femoral vein to the right atrium, with the venous cannula size selected according to the patient's BMI. The femoral cannula was advanced to the right atrium. A guidewire was subsequently placed into the previously prepared right internal jugular vein, and a second venous cannula was advanced to the right atrium. CPB was initiated, the heart was decompressed, and the lungs were disconnected from the ventilator. The sternum was then opened, the old sternal wires were removed, and a redo sternotomy was performed using a specialized saw. Adhesions were carefully bluntly dissected as needed. After the surgical procedure was completed and hemostasis was achieved, a drain was placed in the mediastinum and at least one thoracic cavity (typically the right thorax). The sternum was then closed with steel wires.

Statistical Analysis

Data analysis was conducted utilizing the SPSS software (IBM Corp, released in 2012, Version 27.0 for Windows, Armonk, NY). The conformity of the variables to a normal distribution was assessed with the Kolmogorov-Smirnov test. Descriptive statistical methods (mean, standard deviation, median, frequency, percentage, minimum, and maximum) were used while evaluating the study data. For variables adhering to a normal distribution, group comparisons were executed using the Independent samples t-test. The Pearson chi-squared test was employed for variables not normally distributed to assess the differences in proportions between two independent groups. A p-value of less than 0.05 was deemed indicative of statistical significance.

Results

A retrospective analysis was conducted on 104 patients who underwent redo cardiac surgery between January 2010 and January 2023. Patients were divided into two groups based on the cannulation technique used: PC (n=56) and CC (n=48). Preoperative, intraoperative, and postoperative parameters were collected and analyzed.

Significant differences were found in the prevalence of peripheral artery disease, present in 56.3% of the CC group but absent in the PC group. Other parameters, such as age, BMI, gender distribution, and the prevalence of smoking, hypertension, diabetes, and chronic obstructive pulmonary disease, showed no significant differences between the groups. The distribution of planned surgeries, including bacterial endocarditis, ascending aortic aneurysm, and various valve replacements, was similar across both groups (Table 1).

Significant differences were observed in the CPB time and total operation time, with the PC group having longer durations (127.1±13.6 minutes vs. 120.1±15.4 minutes, p=0.021 and 295.7±40.4 minutes vs. 249.9±39.5 minutes, p<0.001, respectively). Ventilation duration was also significantly shorter in the PC group (5.4±1.1 hours vs. 6.0±1.5 hours, p=0.036). Other parameters, including the number of previous sternotomies, cross-clamp time, chest drainage, ICU stay, and length of hospital stay, showed no significant differences between the groups (Table 2).

Procedure-related injuries, which occurred during resternotomy and primarily involved damage to structures such as the innominate vein, right atrium, right ventricle, or ascending aorta, were recorded separately for both groups. These injuries were significantly less frequent in the PC group (5.4%) compared to the CC group (31.2%) (p=0.036). In addition, significant differences were observed in overall complication rates, which were also lower in the peripheral group (10.7% vs. 35.4%, p<0.001). The use of postoperative blood products, including red blood cells (RBCs), platelets (PLTs), fresh frozen plasma, and fresh whole blood, did not show significant differences between the groups. The requirement for inotropic therapy and the use of intra-aortic balloon pumps were also similar

Table 1. Preoperative parameters and planned surgeries

Age (years)	62.1±8.0	61.5±8.0	0.734
BMI (kg/m²)	27.9±4.8	27.8±4.9	0.667
Female	24 (42.9%)	23 (47.9%)	0.605
Smoke	38 (67.9%)	36 (75.0%)	0.423
HT	29 (51.8%)	27 (56.3%)	0.649
DM	32 (57.1%)	30 (62.5%)	0.579
COPD	26 (46.4%)	17 (35.4%)	0.256
PAD	0 (0.0%)	27 (56.3%)	<0.001
Planned surgeries			0.098
Bacterial endocarditis	2 (3.57)	3 (5.36)	
Ascending aortic aneurysm	5 (8.93)	5 (8.93)	
Aortic valve replacement	19 (33.93)	12 (21.43)	
Mitral valve replacement	30 (53.57)	26 (46.43)	
Tricuspid valve replacement	4 (7.14)	5 (8.93)	
Coronary artery bypass graft	3 (5.36)	4 (7.14)	

BMI: Body mass index, HT: Hypertension, DM: Diabetes mellitus, COPD: Chronic obstructive pulmonary diseas, PAD: Peripheral artery disease

Table 2. Comparison of demographic, laboratory, and operative parameters between peripheral and central cannulation groups

	Peripheral (n=56)	**Central (n=48)**	
	Mean ± SD	Mean ± SD	p-value
Number of previous sternotomies	1.2±0.6	1.1±.2	0.388
Cross-clamp time (min)	102.6±9.3	100.9±12.2	0.819
Cardiopulmonary bypass time (min)	127.1±13.6	120.1±15.4	**0.021**
Total operation time (min)	295.7±40.4	249.9±39.5	**<0.001**
Chest drainage (mL)	839.9±126.2	849.1±122.8	0.510
Ventilation duration (hours)	5.4±1.1	6.0±1.5	**0.036**
Total intensive care unit stay (days)	2.9±1.6	3.0±1.7	0.943
Length of hospital stay (days)	6.8±1.6	7.3±2.1	0.370

SD: Standard deviation

between the groups. There was no significant difference in perioperative (in-hospital) mortality between the groups. Mortality occurred in one patient (1.8%) in the PC group and in two patients (4.2%) in the CC group (p>0.05). The causes of mortality were severe low cardiac output syndrome and multiple organ failure (Table 3).

Preoperative Hb levels were 11.4±1.1 g/dL in the PC group and 11.3±1.1 g/dL in the CC group (p=0.565). Postoperative Hb levels were 8.7±0.6 g/dL in both groups (p=0.741). Preoperative C-reactive protein (CRP) levels were 11.3±7.7 mg/L in the PC group and 13.1±9.5 mg/L in the CC group (p=0.348). Postoperative CRP levels were 101.6±97.6 mg/L in the PC group and 131.0±133.5 mg/L in the CC group (p=0.672). Preoperative ejection fraction (EF) was 44.7±6.7% in the PC group and 45.1±6.4% in the CC group (p=0.757). Postoperative EF was 42.8±7.4% in the PC group and 43.5±6.4% in the CC group (p=0.695). There were no significant differences between the groups for other parameters, including hematocrit and PLT counts, both preoperatively and postoperatively. These findings suggest that both cannulation techniques have similar impacts on these laboratory and cardiac function parameters (Table 4).

Discussion

One of the principal hurdles in repeat cardiac surgeries is the safe execution of the sternotomy. The risk of damaging heart structures during this process can lead to significant bleeding and hemodynamic complication[9]. Until April 2016, CC was the standard approach for all reoperations at our facility; thereafter, we shifted entirely to PC aiming to decrease surgical mortality

Table 3. Clinical and demographic comparison of cannulation methods

	Peripheral (n=56)	**Central (n=48)**	
	Count (%)	**Count (%)**	**p-value**
Postoperative blood products (units)			0.381
Absent	46 (77.9%)	38 (73.1%)	
Red blood cells	3 (5.1%)	4 (7.7%)	
Platelets	4 (6.8%)	2 (3.8%)	
Fresh frozen plasma	5 (8.5%)	4 (7.7%)	
Fresh whole blood	1 (1.7%)	4 (7.7%)	
Inotropic therapy requirement	28 (50)	27 (56.3)	0.524
Procedure related injury			**0.036**
No	53 (94.6%)	33 (68.8%)	
Innominate vein	2 (3.6%)	6 (12.5%)	
Right ventricle	0 (0.0%)	1 (2.1%)	
Right atrium	0 (0.0%)	3 (6.3%)	
Bypass grafts	0 (0.0%)	1 (2.1%)	
Lungs	1 (1.8%)	2 (4.2%)	
Ascending aorta	0 (0.0%)	2 (4.2%)	
Intra-aortic balloon pump	4 (7.1)	4 (8.3)	0.820
Complications			**<0.001**
Absent	50 (89.3%)	31 (64.6%)	
Superficial sternal infection	2 (3.6%)	6 (12.5%)	
Deep sternal infection	0 (0.0%)	5 (10.4%)	
Sternal dehiscence	0 (0.0%)	6 (12.5%)	
Femoral infection	4 (7.1%)	0 (0%)	

Table 4. Pre- and post-operative laboratory and cardiac EF values in redo cardiac surgeries

	Peripheral (n=56)	Central (n=48)	
	Mean ± SD	**Mean ± SD**	**p-value**
Pre-op Hb (g/dL)	11.4±1.1	11.3±1.1	0.565
Post-op Hb (g/dL)	8.7±0.6	8.7±0.6	0.741
Pre-op HCT (%)	34.1±3.2	33.6±3.3	0.586
Post-op HCT (%)	26.5±1.8	26.5±1.9	0.917
Pre-op PLT (10^3/μL)	206.8±78.8	196.1±72.3	0.512
Post-op PLT (10^3/μL)	175.6±77.3	172.8±70.9	0.977
Pre-op CRP (mg/L)	11.3±7.7	13.1±9.5	0.348
Post-op CRP (mg/L)	101.6±97.6	131.0±133.5	0.672
Pre-op EF (%)	44.7±6.7	45.1±6.4	0.757
Post-op EF (%)	42.8±7.4	43.5±6.4	0.695

Hb: Hemoglobin, HCT: Hematocrit, PLT: Platelet, CRP: C-reactive protein, EF: Ejection fraction, SD: Standard deviation

and morbidity rates. Kuralay et al.[3] achieved notable reductions in cardiac injuries and severe bleeding events by employing the Carpentier bicaval venous cannul. In a similar vein, Luciani et al.[4] implemented peripheral CPB as a preparatory measure in selected cases, effectively minimizing injuries upon reentry. Despite the increased duration of both total operation and CPB with PC noted in these studies, our findings indicate that the use of a multi-stage venous cannula for peripheral CPB, without any specific preconditions unlike Luciani et al.[4], resulted in a longer peripheral CPB duration. However, there was no significant difference in the overall surgery time between PC and CC groups. Utilizing presternotomy peripheral CPB can reduce the pressure in the heart and major arteries, thus aiding in the swift and safe separation of adhesions.

Studies have shown that utilizing multidetector CT for preoperative planning is advantageous in evaluating the spatial relationship between the sternum and vital structures beneath it[10,11]. We agree with this assessment but recognize that this technique falls short in providing detailed information about the severity of adhesions. Yoshioka et al.[12] have shown that the integration of tagged cine magnetic resonance imaging with a finite element model offers predictions on the extent of retrosternal adhesions, although this method is not widely used. In our established practice, CT angiography is conducted before conducting aortic surgeries such as the Bentall or David procedures.

In our study, we compared PC with conventional methods in redo cardiac surgeries. Our findings indicate that the PC group experienced a longer CPB time and total operation duration compared to the CC group. Despite these extended times, the PC group demonstrated a lower incidence of procedure-related injuries and overall complications. Additionally, while ventilation duration was shorter in the PC group, the length of hospital stay and ICU stay showed no significant difference between the two groups. Laboratory values and cardiac EF measured preoperatively and postoperatively were also comparable across both groups. These results suggest that PC may offer a safer alternative with fewer complications in redo cardiac surgeries, without adversely affecting the recovery period or clinical outcomes.

Several recent studies have explored the trade-off between PC and operative duration in redo cardiac surgery. Werner et al.[13] highlighted that although PC can provide a safer environment for sternal re-entry by avoiding mediastinal dissection, this comes at the cost of additional preparation time and may extend CPB and

total operative time. Meanwhile, Liu et al.[14] reported a 10-year series in which no significant difference in bypass or operation length was observed between central and peripheral techniques, suggesting that with optimized protocols the time difference may be mitigated. Together, these findings support our interpretation that the longer operative and bypass times in the PC group reflect a deliberate strategy of enhanced safety rather than inefficiency.

In the study by Ata et al.[15], peripheral and CC techniques were compared in cardiac reoperations. This study found that the incidence of procedure-related injuries was significantly lower in the PC group compared to the CC group (1.8% vs. 8.3%). Similarly, in our study, the incidence of procedure-related injuries (5.4% vs. 31.2%) and overall complication rates (10.7% vs. 35.4%) were significantly lower in the PC group. Yildiz et al.[16] also found that procedure-related injuries were lower in the preoperative cannulation group compared to the conventional cannulation group (6.7% vs. 22.5%. Ata et al.[15] study demonstrated that the CPB time was significantly shorter in the CC group (120±26.7 minutes) compared to the PC group (125±31 minutes). Yildiz et al.[16] study showed that the CPB time was shorter in the preoperative cannulation group (141.7±82.47 minutes) compared to the conventional cannulation group (171.87±85.59 minutes), although this difference was not statistically significant. In our study, the CPB time was longer in the PC group (127.1±13.6 minutes) and this difference was statistically significant. While Yildiz et al.[16] study found no significant difference in total operation time between the groups (central: 198±43 minutes, peripheral: 202±47 minutes). Duman et al.[17], the CPB time was shorter in the CC group (141.7±82.47 minutes) compared to the PC group (171.87±85.59 minutes), and the total operation time was significantly shorter in the CC group (314.77±187.38 minutes) compared to the PC group (420.29±188.84 minutes. These findings are consistent with the results obtained in our study. Furthermore, Duman et al.[17] study also found that procedure-related injuries were lower in the PC group compared to the CC group. These data support our study and suggest that PC may reduce complication rates during redo sternotomy. Our study showed that the total operation time was significantly longer in the PC group (295.7±40.4 minutes). In contrast, Yildiz et al.[16] study found that the total operation time was significantly shorter in the preoperative cannulation group (314.77±187.38 minutes) compared to the conventional cannulation group (420.29±188.84 minutes).

The higher incidence of sternal dehiscence and deep sternal infection observed in the CC group can be explained by increased mechanical stress and prolonged mediastinal exposure during re-sternotomy. Repeated manipulation of previously operated tissues may compromise sternal stability and microcirculation, leading to delayed wound healing and a higher susceptibility to infection. Furthermore, extended sternal exposure and rewiring of fragile sternal bone after previous operations may predispose to postoperative instability and deep sternal wound infection. Recent studies have similarly reported that CC and repeated sternal entry are associated with increased mediastinal wound complications[6,7]. These factors likely contribute to the higher rates of sternal-related complications seen in the CC group in our study.

Another notable finding from our study is that there was no significant difference between the groups in terms of postoperative trasfusion. However, the distribution of transfused blood products varied. In the PC group, 77.9% of patients did not require any postoperative blood products, compared to 73.1% in the CC group. RBC transfusions were needed in 5.1% of the PC group and 7.7% of the CC group. PLT transfusions were required in 6.8% of the PC group and 3.8% of the CC group. Fresh frozen plasma was used in 8.5% of the PC group and 7.7% of the CC group, while fresh whole blood was transfused in 1.7% of the PC group compared to 7.7% of the CC group. This variation indicates a trend towards reduced transfusion requirements in the PC group.

Roselli et al.[18] have established a link between reentry injuries and increased perioperative mortalit. Conversely, Ata et al.[15] reported no substantial differences in perioperative mortality between groups, though a higher incidence of injuries was noted in patients undergoing CC. Furthermore, studies by Ellman et al.[19] and Imran Hamid et al.[20] suggest that reentry injuries do not impact the long-term survival of patients who undergo redo surgeries. These patients, if discharged without complications, tend to have favorable long-term survival outcomes. In our analysis, we observed no significant differences in perioperative mortality rates between the peripheral and CC groups. Specifically, hospital mortality occurred in 1.8% of patients in the PC group and 4.2% in the CC group. Despite a higher occurrence of injuries in the CC group, these did not lead to markedly different mortality rates. Additionally, the one-year survival rates were excellent and comparable across both groups.

Study Limitations

There are several limitations to our study. Firstly, as our study has a retrospective design, there may be some biases during data collection and analysis. Additionally, our study is single-centered, which limits the generalizability of the results. Although the demographic and clinical characteristics of the patients were similar between groups, some potential confounding factors might not have been fully controlled during patient selection. The peripheral and CC techniques used in our study may vary based on the surgeons' experience and preference, which could affect the outcomes. Finally, the sample size of our study is limited, and the results need to be confirmed with larger, multicenter studies.

Conclusion

This study demonstrates that PC offers certain advantages over CC in redo cardiac surgeries. PC may reduce the incidence of procedure-related injuries and overall complications. However, CPB and total operation times can be longer. PC may provide a safer alternative with fewer complications. Nonetheless, larger, multicenter, and prospective studies are needed to increase the generalizability of these results and to obtain stronger evidence.

Ethics

Ethics Committee Approval: This retrospective study was approved by the Ethics Committee of tertiary University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital (approval no: 2024-04-05, date: 04.03.2024).

Informed Consent: This retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Toz H, Türkyılmaz S, Concept: Türkyılmaz G, Kuserli Y, Kavala AA, Design: Toz H, Türkyılmaz S, Data Collection and/or Processing: Satılmış OE, Analysis and/or Interpretation: Türkyılmaz G., Satılmış OE, Kavala AA, Literature Search: Kuserli Y, Kavala AA, Writing: Toz H

Conflict of Interest: The authors declare no conflicts of interest concerning the authorship or publication of this article.

Financial Disclosure: This research received no specific grants from any funding agency in the commercial or not-for-profit sectors.

References

1. Saadat S, Schultheis M, Azzolini A, et al. Femoral cannulation: a safe vascular access option for cardiopulmonary bypass in minimally invasive cardiac surgery. Perfusion. 2016;31:131-4. Epub 2015 Jun 1.
2. O'Brien MF, Harrocks S, Clarke A, et al. How to do safe sternal reentry and the risk factors of redo cardiac surgery: a 21-year review with zero major cardiac injury. J Card Surg. 2002;17:4-13.
3. Kuralay E, Bolcal C, Cingoz F, et al. Cardiac reoperation by carpentier bicaval femoral venous cannula: GATA experience. Ann Thorac Surg. 2004;77:977-81; discussion 982.
4. Luciani N, Anselmi A, De Geest R, et al. Extracorporeal circulation by peripheral cannulation before redo sternotomy: indications and results. J Thorac Cardiovasc Surg. 2008;136:572-7. Epub 2008 Jun 25.
5. Tarola C, Fremes S. Commentary: redo cardiac surgery: striving for the best but prepared for the worst. J Thorac Cardiovasc Surg. 2022;164:1767-8. Epub 2021 Jan 28.

6. Rupprecht L, Schopka S, Keyser A, et al. 25 years' experience with redo operations in cardiac surgery-third-time sternotomy procedures. Thorac Cardiovasc Surg. 2022;70:377-83.

7. Brown JA, Kilic A, Aranda-Michel E, et al. The long-term impact of peripheral cannulation for redo cardiac surgery. J Card Surg. 2020;35:1920-6. Epub 2020 Jul 11.

8. Brancaccio G, Perri G, Della Porta M, et al. Use of carotid artery cannulation during redo sternotomy in congenital cardiac surgery: a single-centre experience. Interact Cardiovasc Thorac Surg. 2021;33:119-23.

9. Park CB, Suri RM, Burkhart HM, et al. Identifying patients at particular risk of injury during repeat sternotomy: analysis of 2555 cardiac reoperations. J Thorac Cardiovasc Surg. 2010;140:1028-35.

10. Kamdar AR, Meadows TA, Roselli EE, et al. Multidetector computed tomographic angiography in planning of reoperative cardiothoracic surgery. Ann Thorac Surg. 2008;85:1239-45.

11. Aviram G, Sharony R, Kramer A, et al. Modification of surgical planning based on cardiac multidetector computed tomography in reoperative heart surgery. Ann Thorac Surg. 2005;79:589-95.

12. Yoshioka I, Saiki Y, Ichinose A, et al. Tagged cine magnetic resonance imaging with a finite element model can predict the severity of retrosternal adhesions prior to redo cardiac surgery. J Thorac Cardiovasc Surg. 2009;137:957-62. Epub 2009 Feb 23.

13. Werner P, Winter M, Coti I, et al. State-of-the-art review: advantages and disadvantages of femoral versus central cannulation. innovations (Phila). 2025;20:148-57. Epub 2025 Apr 22.

14. Liu G, Sahdev N, Abdullahia YS, Punjabia P. Central vs peripheral cannulation in redo cardiac surgery - a 10-year review. J Surg. 2024;9:1-5.

15. Ata EC, Erkanli K, Ulukan MÖ, et al. Peripheral vs. central cannulation in cardiac reoperations: technical considerations and outcomes. Braz J Cardiovasc Surg. 2020;35:420-6.

16. Yildiz Y, Ulukan MO, Erkanli K, et al. Preoperative arterial and venous cannulation in redo cardiac surgery: from the safety and cost-effectiveness points of view. Braz J Cardiovasc Surg. 2020;35:927-33.

17. Duman ZM, Kadiroğulları E, Kaplan MC, et al. Central vs. peripheral cannulation during reoperations: a propensity score matching analysis. Braz J Cardiovasc Surg. 2023;38:e20220463.

18. Roselli EE, Pettersson GB, Blackstone EH, et al. Adverse events during reoperative cardiac surgery: frequency, characterization, and rescue. J Thorac Cardiovasc Surg. 2008;135:316-23, 323.e1-6.

19. Ellman PI, Smith RL, Girotti ME, et al. Cardiac injury during resternotomy does not affect perioperative mortality. J Am Coll Surg. 2008;206:993-7; discussion 997-9. Epub 2008 Feb 11.

20. Imran Hamid U, Digney R, Soo L, et al. Incidence and outcome of re-entry injury in redo cardiac surgery: benefits of preoperative planning. Eur J Cardiothorac Surg. 2015;47:819-23. Epub 2014 Jul 9.