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Open Seldinger Technique for Peripheral Cannulation Strategy for Minimally Invasive Cardiac Surgery

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Abstract

Objectives: In minimally invasive cardiac surgery, the cannulation strategy significantly affects the outcome of the procedure. In this study, we aimed to evaluate the perioperative outcomes of patients who underwent Seldinger-guided femoro-femoral cannulation for cardiopulmonary bypass.

Materials and Methods: This retrospective study included 116 consecutive patients who underwent femoral artery and vein cannulation using the open Seldinger method for various minimally invasive cardiac surgeries between August 2020 and January 2022. Femoral artery-vein cannulation was performed in all patients, and a combination of the femoral and jugular veins was performed in 24 patients. Before femoral exploration, both inguinal regions were evaluated with Doppler ultrasound for calcification, stenosis, and vessel diameter, and the site was selected accordingly. After surgical exposure, both vessel cannulations were performed using only purse-string sutures with the help of a guidewire without incision.

Results: Of the patients, 96 (82.8%) had minimally invasive coronary bypass surgery, 12 (10.3%) had mitral valve surgery, 6 (5.2%) had aortic valve surgery, and 2 (1.7%) had tricuspid valve surgery. None of the patients presented with stroke, peripheral arterial ischemia, or deep vein thrombosis. No perioperative vascular injuries or bleeding complications occurred. No deep wound infections or pseudoaneurysms were observed in the early and late postoperative periods. Only two patients underwent primary suturing with superficial skin revision due to impaired superficial wound healing, and two patients had seroma that healed completely with a single puncture.

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Conclusion: According to the results obtained from our case series, the open Seldinger-guided femoral cannulation technique is a reliable method in cardiac surgery because it minimizes the risk of complications and can be easily and quickly applied. We believe that this procedure can be performed effectively and successfully in patients scheduled for peripheral cannulation for cardiopulmonary bypass.

Keywords: Seldinger technique, femoral cannulation, cardiopulmonary bypass

Introduction

Minimally invasive cardiac surgery (MICS) has grown in popularity over the past two decades. Cardiopulmonary bypass (CPB) has an important place in this popularity and growth. CPB techniques have been developed and are periodically renewed since its first successful use by John Gibbon in 1953[1]. Today, some cardiac surgeries requiring sternotomy have been replaced by minimally invasive thoracotomy methods, leading to changes in CPB strategies. The necessity of peripheral cannulation instead of central cannulation has resulted in some disadvantages, such as an increased incidence of vascular complications and cerebrovascular events[2]. Despite this, innovative studies aimed at increasing the success and reliability of peripheral cannulation techniques continue to increase their prevalence.

Cannulation techniques and strategies are the basic elements of MICS, and different methods may be required depending on the type of operation[2]. The most important factor determining the success and effectiveness of each surgical procedure is the cannulation method. The most commonly used approaches for MICS with CPB are established through a femoral artery-vein cannulation, with occasional internal jugular vein combined with femoral vein cannulation[3]. The procedure has become more preferred due to its rapid application, good cosmetic results, faster recovery and less tissue trauma.

In daily practice, peripheral cannulation is performed by the percutaneous approach or traditional open surgical cannulation techniques[4,5]. The surgical team's belief in the effectiveness, success, and reliability of the method and their own clinical experience are effective in the selection of cannulation. In this study, we aimed to evaluate the effectiveness and reliability of the open Seldinger-guided femoro-femoral cannulation technique that we have been using for years as a contribution to the efforts to develop an ideal peripheral cannulation technique.

Materials and Methods

We retrospectively analyzed 116 patients who underwent open Seldinger-guided femoro-femoral cannulation for CPB in MICS between August 2020 and January 2022. Institutional Ethics committee approval was obtained from the Institutional Ethics committee approval was obtained from the Health Sciences University, Ümraniye Training and Research Hospital Ethics Committee (approval no.: B.10.1.TKH.4.34.H.GP.0.01/35, date: 10.02.2022).

All patients were preoperatively evaluated with computed tomography (CT) angiography for suitability for cannulation. Femoro-femoral cannulation was applied to all patients included in the study. Jugular vein cannulation was combined with cannulation in patients with body surface area (BSA) >2 m^2 or inadequate venous return. Both artery and vein cannulation processes were guided by transesophageal echocardiography (TEE). Patients were examined in detail according to the types of cardiac surgery performed (coronary bypass surgery, mitral valve surgery, aortic valve surgery, tricuspid valve surgery, etc.), site of cannulation (femoral, jugular or combined), vessel diameters and calcification status, and intraoperative and postoperative results.

All patients were analyzed in terms of preoperative demographic data and comorbidities (diabetes mellitus, chronic obstructive pulmonary disease, etc.),

intraoperative arterial and venous injury, lower extremity ischemia, stroke, wound infection, deep and superficial thrombophlebitis, hematoma, seroma, and wound healing. Cardiac surgery cases involving axillary/subclavian artery cannulation were excluded from the study.

Surgical Technique

Preoperatively, all patients underwent CT angiography to exclude serious calcification or stenosis that could cause complications in the descending aorta and iliofemoral artery. Surgical planning was performed for patients who were suitable for peripheral cannulation according to CT angiography. A TEE probe was placed in all patients to guide the peripheral cannulation procedure before surgery.

Although all patients were evaluated with preoperative CT angiography, regional femoral artery and vein diameter and calcification evaluation was performed with Doppler ultrasound in the operating room to select the site of the femoral region, and the vessel trace was marked. In general, when no vessel diameter abnormality or local calcification was detected, the right-sided cannulation site was preferred. In all patients, an approximately 2-3 cm oblique incision known as a bikini incision was applied parallel to the inguinal ligament. Subcutaneous tissues were dissected vertically. The femoral artery and vein were reached, and only the anterior surfaces of the vessels were isolated from the surrounding tissues. The tissues on the sides and backs of both vessels were dissected to ensure that the vessels remained stable and fixed. Purse-string sutures were made with 5-0 Prolene (Figure 1) to the anterior vessels. Heparinization was then administered at an appropriate dose. First, an 18G needle was inserted into the purse string for femoral vein cannulation (Figure 2). A 0.038 guidewire was guided through the needle into the inferior vena cava under TEE guidance. Depending on the patient's weight, we used a 24-26 Fr venous cannula. After removal of the needle, the vessel was first dilated with a vessel dilator, and the cannula was advanced over the guidewire using the Seldinger technique. Then, with TEE control, the cannula was passed from the inferior vena cava to the right atrium and was connected to the venous circuit. The same strategy was applied to the femoral artery. It was ensured that the guidewire was in the descending aorta under TEE guidance. Femoral artery cannulation was performed using 19-Fr to 21-Fr cannulas. After de-airing, the arterial cannula is connected to the arterial circuit. Both cannulas were secured to the snare by clamping the purse-string down. No valvulotomy or vascular clamp was used. CPB was initiated after the completion of cannulation.

After the operation is completed, when the patient is to be weaned from the extracorporeal circulation, venous decannulation is first performed and the purse-string is tied without using any clamps. Then, arterial decannulation is performed and the purse-string is tied (Figure 3). An additional suture is usually placed on the first purse string to reduce the risk of arterial bleeding

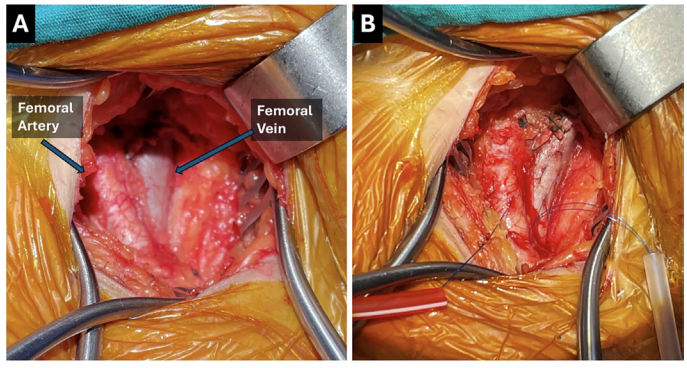

Figure 1. (a) Femoral artery and vein exploration (b) Placement of purse-string suture

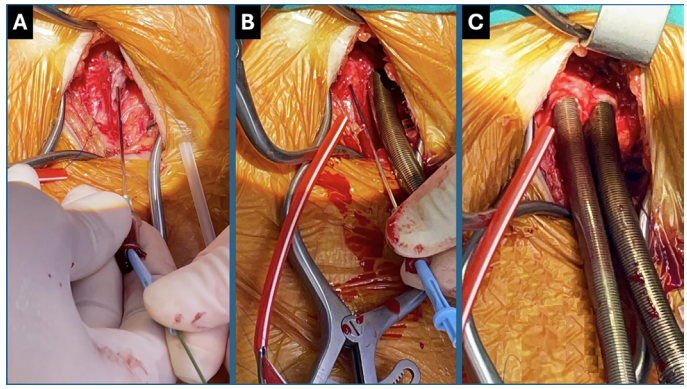

Figure 2. (a) Placement of guidewire through needle with Seldinger technique in femoral vein, (b) application of Seldinger technique in femoral artery, (c) after femoral artery-vein cannulation

and possible postoperative complications. After bleeding control, the subcutaneous tissue is sutured in accordance with the procedure. The subcutaneous skin tissue is closed with sutures in an esthetic manner and the operation is concluded.

Statistical Analysis

Statistical analysis SPSS (IBM, Version 21.0) was used for statistical analysis. Normal distribution continuous variables are expressed as the mean ± standard deviation The Kolmogorov-Smirnov test confirmed data normality.

Results

Data of 116 patients who underwent open Seldinger-guided peripheral cannulation were reviewed. All patients underwent MICS. 84 (72.4%) of the patients were male and 32 (27.6%) were female, and the average age of the patients was 58.12±10.72; mean body mass index was 24.26±4.35; and 51 (43.96%) patients were diagnosed with diabetes and 45 (38.79%) patients with hypertension. The baseline demographic and clinical characteristics of the patients are presented in Table 1.

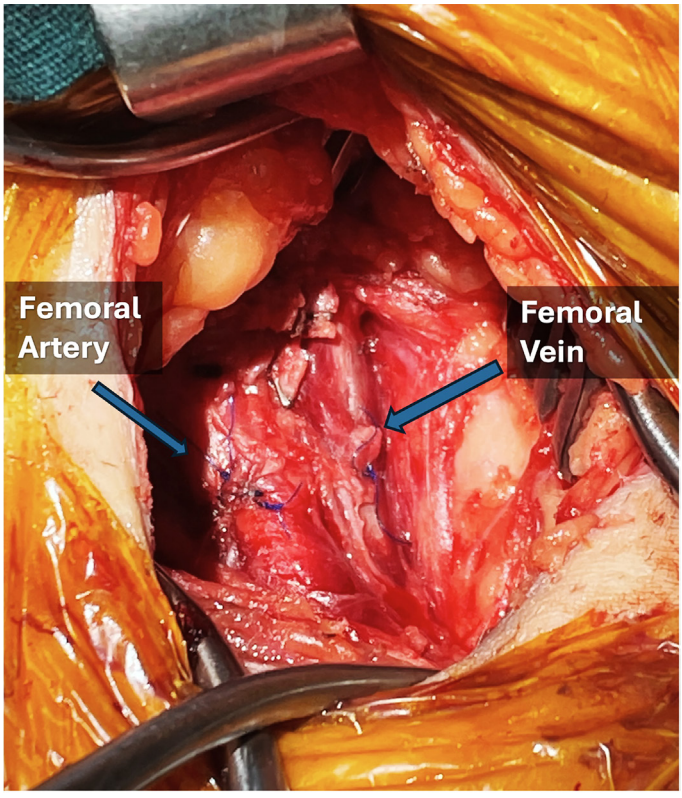

Figure 3. After tying purse-string sutures following decannulation of the femoral artery and vein

Ninety six (82.8%) patients underwent coronary bypass surgery, 12 (10.3%) underwent mitral valve surgery, 6 (5.2%) underwent aortic valve surgery, and 2 (1.7%) underwent tricuspid valve surgery (Table 2). According to the Doppler ultrasound results obtained in the operating room, the mean femoral artery diameter of the patients was 9.52±1.42 mm and the mean femoral vein diameter was 10.61±3.12 mm (Table 3).

Peripheral cannulation was successfully performed in all patients. All patients who underwent surgery were treated with femoral artery and vein cannulation. The mean CPB time was 139.52±30.45 minutes. Only 24 patients underwent jugular vein cannulation. All jugular

Table 1. Baseline characteristics

	n=116
Male/Female	84/32
Age (Mean ± SD)	58.12±10.72
Hypertension, n (%)	45 (38.79%)
Diabetes mellitus, n (%)	51 (43.96%)
Hyperlipidemia, n (%)	41 (35.34%)
COPD, n (%)	23 (19.8%)
Smoker, n (%)	39 (33.6%)
BMI (Mean ± SD)	24.26±4.35

SD: Standard deviation, COPD: Chronic obstructive pulmonary disease, BMI: Body mass ındex

Table 2. MICS distribution and CPB time

	n=116 **Grup I (n=64)**
Coronary bypass surgery	96 (82.8%)
Mitral valve surgery	12 (10.3%)
Aortic valve surgery	6 (5.2%)
Trikuspit valve surgery	2 (1.7%)
	2 (%19.4)
CPB time (min) (Mean ± SD)	139.52±30.45

MICS: Minimally invasive cardiac surgery, CPB: Cardiopulmonary bypass, SD: Standard deviation

cannulations were performed using an ultrasound-guided percutaneous method, and no complications were encountered during or after the procedure. In two patients in whom pump pressure was high and sufficient flow was not achieved after femoral artery cannulation, adequate perfusion values were achieved by cannulating the opposite femoral artery. In one patient, CPB was performed with double femoral artery cannulation due to stenosis in both femoral arteries and slow flow rate.

No femoral artery-vein injury, dissection, rupture, or dilator-related injury was observed during the operation. No lower extremity arterial embolism or stroke was noted during the postoperative period. Only one patient encountered a situation requiring the use of a vascular clamp due to intraoperative moderate arterial bleeding due to inadequacy of purse-string sutures after arterial decannulation, and the vessel was repaired with primary suture. No deep wound infection or dehiscence was observed in any patient in the early or late period, superficial tissue healing disorder was observed in only two patients with diabetes, and complete healing was achieved with superficial debridement and primary skin suturing. Subcutaneous seroma was observed in two patients, and complete healing was achieved by single needle aspiration. Deep vein thromboembolism was not observed in any patient. However, superficial thrombophlebitis in the leg was observed in 2 (1.7%) patients who underwent endoscopic resection of the saving vein. No late bleeding, hematoma, or pseudoaneurysm was observed (Table 4).

Table 3. Vascular measurements and cannula sizes

	n=116
Femoral artery diameter (mm) (Mean ± SD)	9.52±1.42
Femoral vein diameter (mm) (Mean ± SD)	10.61±3.12
Femoral artery cannula size	19-21 Fr
Femoral vein cannula size	24-26 Fr
SD: Standard deviation	

Table 4. Postoperative outcomes

	n=116 Grup I (n=64)
Superficial thrombophlebitis	2 (1.7%)
Superficial femoral wound infection	2 (1.7%) 2 (19.4%)
Seroma	2 (1.7%)
Peripheral/cerebral embolism/ischemia	0
Pseudoaneurisma	0
Reoperation for bleeding	0
Hematoma	0
In-Hospital stay (day) (Mean ± SD)	5.4±3.1
SD: Standard deviation	

In-hospital survival was 99.1%. The mean length of hospital stay was 5.4±3.1 days. No prolonged hospital stay or additional comorbidities due to peripheral cannulation were encountered.

Discussion

The popularity of MICS continues to increase worldwide because of its cosmetic benefits and contribution to patient recovery[6-8]. The development of minimally invasive techniques for cardiac surgery has necessitated the development of different cannulation strategies[9]. The best cannulation strategy is still one of the most popular topics in MICS. The major reason for this is that the cannulation strategy directly affects the outcomes of overall cardiac surgery.

Although different methods have been tried since minimally invasive methods were first developed, the most common cannulation strategy has been peripheral approaches[10]. Lamelas et al.[10] showed the advantages and disadvantages of peripheral cannulation in their studies evaluating different cannulation strategies, and the results obtained showed that it still requires optimization.

The most commonly applied peripheral cannulation methods include percutaneous, conventional open, and surgical methods with some modifications. Moschovas et al.[11] performed percutaneous femoral cannulation in 353 of 445 patients who underwent MICS. Percutaneous groin cannulation for establishing CPB in minimally invasive valve surgery significantly reduces the operation time. The percutaneous group had local dissections (n=2) and stenoses (n=3). There was 1 hematoma in both groups.

There were 2 vascular injuries in the percutaneous group (n=2), leading to conversion to surgical access[11]. This study showed that although the incidence of complications appeared to be low, taking this risk, which may affect the outcomes of total cardiac surgery, is an important topic of discussion. In recent years, Saeed et al.[12] compared percutaneous and open femoral cannulation in their study. 88 patients (17%) out of 524 patients who underwent MICS were cannulated using the percuraneous approach and 436 (83%) were cannulated using the surgical approach. They emphasized that the results between the two groups were similar. It should not be overlooked that the clinical and surgical outcomes are parallel to the experience and habits of the team regarding that strategy and technique. We would like to emphasize the open femoral cannulation strategy applied with the modified Seldinger-guided technique, which we have adopted within the scope of all our surgical and clinical experiences and consider the safest method due to the successful results we have obtained.

The negative experiences and serious complications of peripheral cannulation in the early years of MICS have made surgeons cautious about this method for a while. However, the selection of the right patient, exclusion of inappropriate patients, and determination of cannulation strategies are meticulously managed. If we consider the open Seldinger-guided method in its entirety, it is an inseparable part of MICS. This method requires meticulous management during the preoperative, intraoperative, and postoperative stages. One of the most important topics that should be emphasized for the successful and safe completion of this strategy is the evaluation of patients undergoing preoperative CT angiography[13,14]. Therefore, CT angiography is the gold standard method and has been a valuable guide for surgeons in determining the preoperative cannulation strategy. In our case series, we evaluated all patients with preoperative CT scan and excluded the presence of atheromatous plaques or stenosis in the aorta, iliac, and femoral regions. In this way, we minimized the risk of cerebrovascular embolism due to retrograde perfusion. It is also very useful for confirming whether there is any stenosis, vascular torsion, or anatomical variation that will cause an increase in arterial perfusion pressure. It is certain from our experience that CT angiography evaluation is our indispensable guide to minimize MICS-related mortality and morbidity.

In addition, in the open Seldinger-guided method, double-checking the vessel diameter with Doppler ultrasound immediately before operation in the operating room is very important[15]. In all cases, we routinely performed preoperative femoral artery-vein marking in the operating room and determined the better side for the intervention. With doppler ultrasound, the side with the appropriate vessel diameter and structure is determined, thereby minimizing possible additional interventions and possible complications. The use of this procedure contributes to the determination of the optimum cannula size, especially for female patients with narrow vessel diameters.

Another advantage of the open Seldinger-guided peripheral cannulation technique is that vascular manipulation is minimal[16]. In this method, dissection of the anterior part of the vessel is sufficient, and dissection of the lateral and posterior parts is not required. In this way, the vessel remains fixed during cannulation in calcified vessels, and manipulations such as traction in different directions are not required; thus, complications such as plaque rupture or embolism can be minimized. In addition, minimal dissection and vascular manipulation in the inguinal region prevents damage to the lymphatic system, which is abundant in this region. Therefore, the risk of lymphorrhea or seroma during the postoperative period should be minimized. In our entire patient series, two cases of seroma that we observed and complete recovery with only one needle aspiration are concrete evidence of this theory.

In peripheral cannulation strategies, jugular vein cannulation may need to be added for double venous cannulation. As a general approach, percutaneous jugular

vein cannulation is cases where the patient's BSA is > 2.0 m². Jugular vein cannulation can be safely performed by the percutaneous method. Chennakeshavallu et al.[17] also reported successful results of ultrasound-guided jugular vein cannulation in their study. This method is generally accepted as the most common, simple, fast, and reliable method for surgical practice. We did not encounter any perioperative complications in the ultrasound-guided percutaneous jugular vein cannulation we applied in a total of 24 patients in our case series, and we only adopted this method for jugular cannulation. Nevertheless, in surgical practice, venous drainage may not be provided at an adequate level despite jugular vein cannulation. In such cases, the vacuum-assisted device can be safely initiated. Gambino et al.[18], emphasized the features of this method and its safe use in their study of vacuum-assisted venous drainage. In our case series, we also used the vacuum-assisted venous drainage method in 7 patients due to insufficient venous drainage and benefited from it. However, it should not be forgotten that the vacuum-assisted method requires a careful and experienced perfusionist. An excessive increase in negative pressure can cause cell destruction and organ damage; therefore, it should be closely monitored with liver and kidney function tests during the postoperative period.

One of the greatest advantages of the open Seldinger-guided technique is that no incision is made in the vessels. The cone-tipped dilator, which enters the needle hole and gradually widens the hole in the vessel, also minimizes the risk of bleeding and leakage during the intraoperative process. Based on our experience, we recommend that instead of pushing the cannula directly into the vessel lumen during cannulation or decannulation, it is safer to move the cannula within the lumen by rotating it intermittently. In narrow-diameter lumens, the vessel wall may stick to the cannula, and instead of pushing it in the longitudinal axis, circular rotation of the cannula facilitates its safe sliding on the vessel wall. In addition, the fact that there is no need to use a vascular clamp in the open Seldinger-guided technique is advantageous. The use of a vascular clamp can inevitably cause trauma to the vascular wall and possible fracture or rupture of the calcified plaque structure.

A problem that may be encountered intraoperatively after peripheral cannulation is high arterial perfusion pressure. In this case, continuous extracorporeal circulation at high pressure may cause embolism or dissection because of plaque rupture from the vessel wall. The advantage of the open Seldinger technique is that, if such a situation is encountered intraoperatively, cannulation can be quickly transferred to the other femoral region. Even when the perfusion pressure remains high, arterial perfusion can be continued with bilateral femoral artery cannulation. In one of the cases in our series, we completed CPB without any complications by providing optimum pressure with bilateral femoral artery cannulation due to high femoral artery perfusion pressure.

Another advantage of the open Seldinger-guided technique is that since the vessel is not compressed around the cannula with a snare, blood flow to the distal side of the cannula is not completely interrupted. In this way, the risk of lower extremity ischemia is minimized due to partial blood flow to the distal cannula. In our case series, we did not use an additional perfusion catheter for distal perfusion in any of our patients in whom we applied this method, and we did not observe lower extremity ischemia or ischemia-perfusion injury in any of our patients. Although the need for distal perfusion in cardiac surgery is at an acceptable level, it is insufficient in cases of prolonged ECMO need[19]. It requires additional methods, such as the application of distal perfusion catheters. Use of the cannula/femoral artery (C/FA) diameter index as a predictive value for distal perfusion may be beneficial. Nishijima et al.[20] suggested the use of a distal perfusion catheter (DPC) when the C/FA is <0.7 in their study. Their study showed that their strategy for preventing symptomatic ischemia was reasonable and could be almost achieved without DPC when the C/FA is <0.7. C/FA also predicts asymptomatic potential ischemia, and proactive DPC is preferable when the C/FA is ≥0.7. In our

case series, C/FA was <0.7 in measurements. The results obtained seem to support this study.

Although we mentioned that our patients preferred the femoral artery for peripheral cannulation, the axillary artery option should not be forgotten as another access route. Axillary cannulation is an alternative for patients who are not suitable for femoral cannulation due to various comorbidities. We achieved successful results in a limited number of cases of axillary cannulation using the open-seldinger technique. Therefore, although we advocate that this method can also be used for axillary cannulation, studies with larger patient volumes are needed on this subject.

When we make a general evaluation, it is evident that this technique is advantageous due to its contributions, such as direct vision, under-control of the vessel, rapid intervention, and post-procedure safety. The success and reliability of this technique will increase in direct proportion with the increasing experience of surgeons. It can be accepted that we did not compare our results with those of other techniques. However, we believe that the effectiveness and success of our results will contribute to science when compared with the results in the literature. However, it is still accepted that larger volumes and comparative studies are needed for definite superiority statements.

Study Limitations

Although the findings of this study suggest that the open Seldinger-guided femoro-femoral cannulation technique is an effective and safe approach for peripheral cannulation in MICS, several limitations should be acknowledged. The study was retrospective in nature, which inherently limits the ability to draw causal inferences. Retrospective data analysis may be subject to selection bias because the decision to use the open Seldinger-guided technique was based on the surgical team's clinical experience. Although the study included 116 patients, certain subgroups, such as those undergoing a specific types of surgery, were relatively small. This limited sample size may reduce the impact of outcomes for this group.

Conclusion

The data we obtained from our study showed that the open Seldinger-guided technique can be applied effectively, quickly, and safely in patients undergoing peripheral cannulation.

This technique minimizes surgical trauma by reducing the manipulation of the vessels. Faster application of the surgical procedure, continuation of distal blood flow during CPB, and less tissue trauma reduce the risk of complications and contribute to the patient's cosmetic results and recovery. We recommend the use of this technique because of all the advantages and successful results.

Ethics Committee Approval: Institutional Ethics committee approval was obtained from the Health Sciences University, Ümraniye Training and Research Hospital Ethics Committee (approval no.: B.10.1.TKH.4.34.H.GP.0.01/35, date: 10.02.2022).

Informed Consent: Informed consent was obtained from all patients.

Footnote

Authorship Contributions

Surgical and Medical Practices: Sicem H, Çaynak B, Concept: Sicem H, Çaynak B, Design: Sicem H, Data Collection and/or Processing: Sicem H, Analysis and/or Interpretation: Sicem H, Çaynak B, Literature Search: Sicem H, Writing: Sicem H.

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