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Central vs Percutaneous Peripheral Femoral Venous Cannulation in Minimally Invasive Aortic Valve Replacement through Ministernotomy

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ABSTRACT

Background: Minimally invasive aortic valve replacement (MIAVR) through mini-sternotomy represents an evolving surgical technique in the management of valvular heart disease, and this study aims to compare central versus percutaneous peripheral femoral venous cannulation strategies in MIAVR with respect to surgical exposure, wound length, cardiopulmonary and ischemic times, and postoperative outcomes. Objective: to assess visibility and exposure of surgical field, wound length, in patients undergoing Minimally invasive aortic valve replacement (MIAVR) through mini-sternotomy. And to compare between central cannulation and percutaneous peripheral femoral venous cannulation in MIAVR through mini-sternotomy regarding total bypass time, ischemic time during cardiopulmonary bypass, hospital stay and postoperative complications. Patients and Methods: A prospective observational study included 30 patients who underwent MIAVR through mini-sternotomy at Cardiothoracic surgery department, Kasr Al Ainy Hospital between July 2024 and January 2025 were included and were divided into 2 groups according to their cannulation type: Group A: consists of 15 patients who were subjected to Central venous Cannulation. Group B: consists of 15 patients who were subjected to Peripheral venous cannulation. Results: Mean bypass time in studied patients was 102.87±14.2 minutes. Mean ischemic time was 80.27±13.7 minutes. Vacuum assisted drainage was needed in 33% of patients (5 patients) in peripheral venous cannulation group. Re-exploration was done among 6.7% of patients in both groups. Regarding mortality, we found that 1 patient (6.7%) of group A died while there were no recorded cases of postoperative mortality in Group B (P=0.483). Of the 15 patients that underwent central venous cannulation, 2 (13.3%) patients developed severe pericardial effusion. Patients subjected to central venous cannulation has a significantly longer incision when compared to patients in the peripheral venous cannulation group (9.8±0.98 vs 6.73 ±1.12 cm; P=0.003). Conclusion: Percutaneous peripheral femoral cannulation provides a safe alternative to central venous cannulation for cardiopulmonary bypass with a smaller incision length. When comparing central and femoral venous cannulation, we found no significant difference in the postoperative complication rates and overall mortality.

KEYWORDS: Minimally invasive aortic valve replacement; percutaneous peripheral femoral venous cannulation; central venous cannulation.

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INTRODUCTION

Valvular heart disease is a rapidly growing cause of global cardiovascular morbidity and mortality with diverse and evolving geographic distribution.[1]

The management of aortic valve disease has benefited substantially from the introduction and international application of transcatheter aortic valve replacement (TAVR), particularly for patients deemed at prohibitive, high, or intermediate risk.[2]

The surgical approach will often dictate the appropriate cannulation strategy needed to facilitate optimal exposure and ease of operation. Conventional sternotomy-based surgery typically utilizes central ascending aortic cannulation, along with right atrial or bicaval cannulation. In contrast, MICS approaches vary widely and therefore require a wide array of cannulation options[3].

Commonly employed approaches to MICS include performing an upper hemisternotomy, lower hemisternotomy, manubrial approach, and a right mini-thoracotomy. Often, hemisternotomy approaches utilize conventional central arterial and venous cannulation. However, some surgeons may undergo percutaneous femoral venous cannulation, in combination with central arterial cannulation. Alternatively, a completely femoral platform can be utilized.[3]

This study aimed to compare between central and percutaneous peripheral femoral venous cannulation in minimally invasive aortic valve replacement through upper ministernotomy.

Patients and Methods

This prospective observational study included 30 patients who presented to Kasr Al Ainy Faculty of Medicine, Cairo University, between July 2024 and January 2025 with a confirmed diagnosis of aortic valve disease. All patients underwent aortic valve replacement (AVR) via ministernotomy.

Patients were divided into two groups based on their venous cannulation strategy according to the surgeons' preference:

- **Group A (Central Venous Cannulation):** 15 patients underwent central venous cannulation via the common atrium.
- **Group B (Peripheral Venous Cannulation):** 15 patients underwent percutaneous femoral venous cannulation.

Inclusion Criteria

- Patients of any age and sex undergoing minimally invasive AVR via ministernotomy.

Exclusion Criteria

- Full sternotomy
- AVR with concomitant surgery
- Patients requiring aortic root enlargement
- Thoracotomy incision

Ethical Considerations

Approval of the ethics committee, **Faculty of Medicine, Cairo University**, was obtained (Code: **MS-272-2024**).

- Patients' data was kept confidential.
- There is a written informed consent that was previously signed by the patients undergoing aortic valve replacement surgery.
- Informed consent was obtained from all study participants.
- Participants were enrolled on a voluntary basis after approval of the Ethical and Scientific Committee in the Department of Cardiothoracic Surgery.
- Written informed consent was obtained from each participant fulfilling the inclusion criteria after explanation of the purpose of the study.

Data Collection

Data were collected at three stages: preoperative, intraoperative, and postoperative.

Preoperative Data

- Patient history: age, sex, weight, height, cardiac symptoms (e.g., chest pain, dyspnea, paroxysmal nocturnal dyspnea, orthopnea, lower limb edema, palpitations), systemic involvement, and family history.
- Physical examination: general and local examinations (vital signs, inspection, palpation, percussion, auscultation).
- Routine laboratory tests: CBC, coagulation profile, liver and kidney function tests, electrolytes.
- Imaging: electrocardiography (ECG), chest X-ray (CXR), echocardiography, and coronary angiography.

Intraoperative Data

- Cardiopulmonary bypass (CPB) and ischemic times
- Venous cannula size
- Need for additional central venous cannulation or vacuum-assisted drainage in the peripheral group
- Intraoperative complications and conversion to full sternotomy

Postoperative Data

- Wound length
- Use of inotropes
- Reoperation during hospital stay
- Postoperative complications

Surgical Technique

All procedures were performed by experienced cardiac surgeons specializing in minimally invasive aortic valve replacement (MIAVR). A standardized surgical approach was followed for all patients to ensure consistency in technique and outcome assessment.

Patient Positioning and Anesthesia

- Patients were placed in the supine position with arms tucked to the sides.
- General anesthesia was administered, and endotracheal intubation was performed.

- Transesophageal echocardiography (TEE) was used intraoperatively to assess cardiac function, guide cannulation, and confirm de-airing before weaning from cardiopulmonary bypass (CPB).

Surgical Approach: Ministernotomy

- A J-shaped ministernotomy was performed, extending from the manubrium to the third (in peripheral cannulation group) or fourth intercostal space (in central cannulation group).
- The pericardium was opened in a longitudinal fashion and suspended to provide optimal exposure.

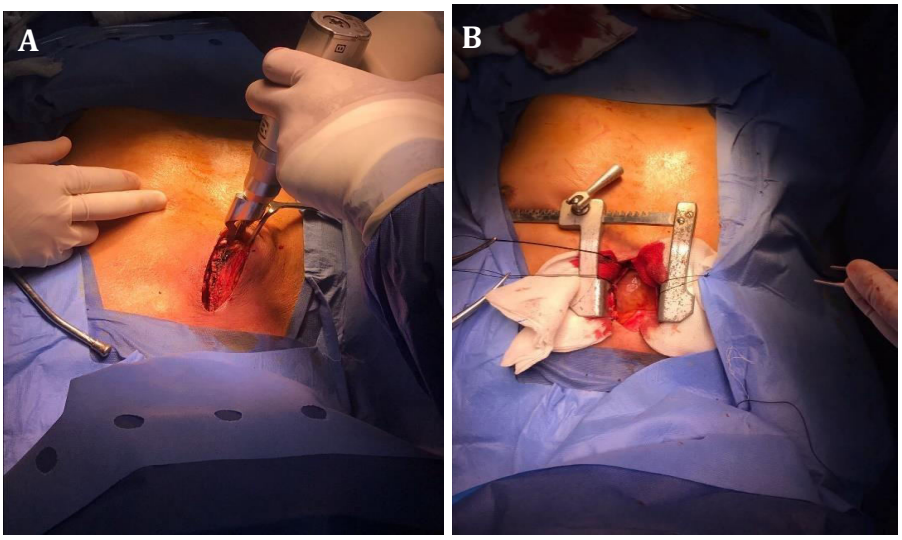

Figure (1): Patient undergoing AVR through ministernotomy (a) opening of a J shaped ministernotomy. (b) suspension of pericardium through ministernotomy.

Cannulation Strategy: The ascending aorta was cannulated directly for arterial inflow. Selection of venous cannula size was based on the patient's BMI. Patients were assigned to one of two venous cannulation techniques according to the surgeons' preferences:

❖ **Central Venous Cannulation Group**

- The common atrium was cannulated directly using a double-stage cannula, and the cannula was directed towards the inferior vena cava (IVC).

❖ **Percutaneous Peripheral Femoral Venous Cannulation Group**

- The femoral vein was identified using anatomical landmarks.
- A large-bore needle was inserted into the femoral vein and aspirated to confirm venous access.
- A J-tip guidewire was advanced through the needle and into the femoral vein; proper guidewire placement was confirmed by TEE, and a dilator was then used.
- The appropriate-sized multistage (23F–25F) cannula was inserted and advanced toward the right atrium, with cannula positioning monitored by TEE.
- Once the cannula was correctly placed, it was secured to the skin using sutures.

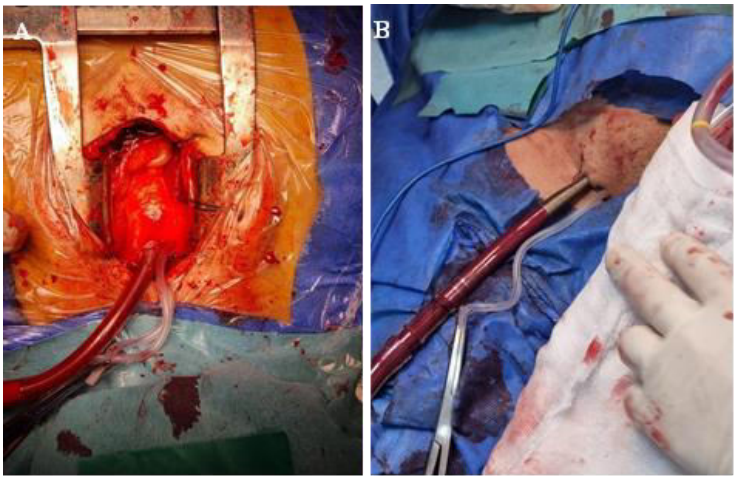

Figure (2): (a) Ascending Aorta cannulation for arterial access. (b) Percutaneous femoral venous cannulation

Cardiopulmonary Bypass (CPB) and Myocardial Protection

- Standard CPB techniques were used with a targeted core temperature of 28–30°C for mild hypothermia.
- Myocardial protection was achieved via antegrade cold blood cardioplegia through the coronary ostia directly or through the aortic root according to the dominant pathology of the aortic valve.
- The heart was arrested, and the aortic valve was exposed through a transverse aortotomy.

Aortic Valve Replacement Procedure

- The diseased aortic valve leaflets were excised, and annular debridement was performed.
- An appropriately sized bioprosthetic or mechanical valve was implanted using interrupted pledgeted sutures.
- The aortotomy was closed with running 4-0 or 5-0 polypropylene sutures.

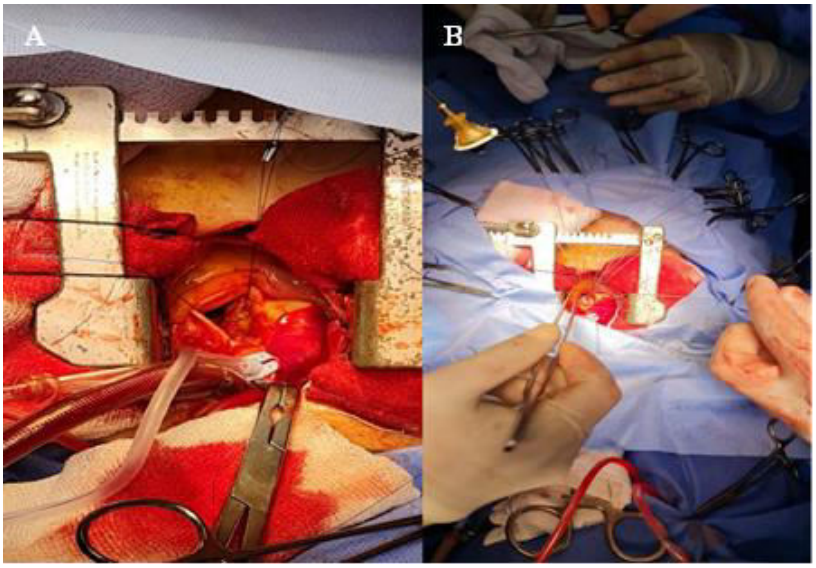

Figure (3): (a) Commissures suspension by prolene sutures to elevate aortic annulus. (b) Interrupted pledgeted sutures to implant prosthetic valve.

Weaning from CPB and Hemostasis

- De-airing maneuvers were performed to prevent embolic events.
- The patient was gradually weaned from CPB under TEE guidance.
- Hemostasis was meticulously achieved; the venous cannula was removed with the start of protamine sulfate administration.
- The femoral venous cannula was removed, and manual compression was applied for 15 minutes to ensure no bleeding occurred. A compression bandage was then applied for the next 6 hours postoperatively.

Closure and Postoperative Care

- The sternum was reapproximated with sternal wires, and soft tissue layers were closed in a standard fashion.
- Patients were transferred to the intensive care unit (ICU) for postoperative monitoring, including hemodynamic stabilization and early extubation.
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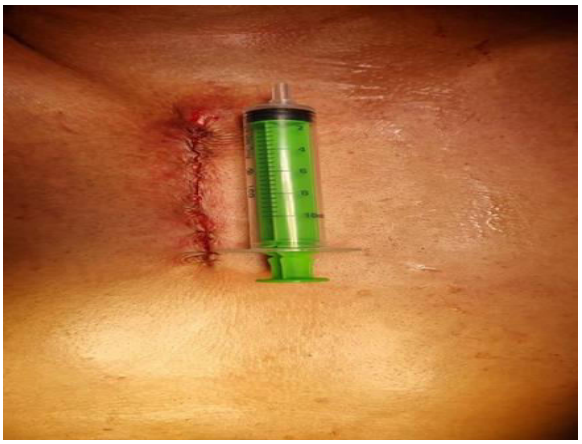

Figure (4): Ministernotomy wound post wound closure

Study Outcomes

Primary Outcome

- Length of wound.

Secondary Outcome Parameters

1. Comparison of total bypass time.
2. Ischemic time during CPB.
3. Hospital stays duration and complications.

Sample Size

After reviewing the literature, we determined that with a power of 90% and an α error of 5%, the minimum required sample size is 30 patients diagnosed with aortic valve disease by echocardiography.

Patients were allocated in a 1:1 ratio into two groups based on their management strategy:

- **Group A:** 15 patients undergoing AVR via ministernotomy with central venous cannulation.
- **Group B:** 15 patients undergoing AVR via ministernotomy with percutaneous femoral venous cannulation.

Statistical Analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) software for Windows.

- **Categorical data** was described in terms of frequencies and percentages.
- **Numerical data** was described in terms of mean and standard deviation if normally distributed, and median with interquartile range if not normally distributed.
- **Kolmogorov–Smirnov test** was used to test the normality of distribution of numerical variables.
- **Chi-square test** was used to assess the association between categorical variables.
- **Independent sample t-test** was used to test the difference between two groups concerning parametric numerical variables.
- A **P value < 0.05** was considered statistically significant.

RESULTS

A total of 30 patients were eligible to participate in the study. Their age ranged between 18 and 73 years, with a mean of 46.5 ± 15.9 years. Both genders were nearly equally distributed, with 53.3% of patients being males.

Hypertension was the most common associated comorbidity among included patients, with a prevalence of 43.3% (13 patients), followed by diabetes mellitus in 36.7% (11 patients). Additionally, 23.3% (7 patients) were suffering from COPD.

All patients underwent preoperative echocardiography. The mean preoperative ejection fraction was 62.13 ± 5.97%. Among the included patients:

- 40% (12 patients) suffered from aortic stenosis (AS).
- 50% (15 patients) had aortic regurgitation (AR).
- 10% (3 patients) had double lesions (combined AS and AR).

There were no statistically significant differences between the two groups regarding age, sex, BMI, comorbidities, or preoperative echocardiographic findings, as shown in **Table (1).**

Table (1): Sociodemographic characteristics among included patients (30 patients).

Variable	Central cannulation group N=15	Peripheral cannulation group N=15	P Valve
Age (years) Minimum Maximum Mean ± SD	 18 72 45 ± 16	 24 73 48±15.8	 0.63
Gender* Male Female	 8(53.3) 7(46.7)	 8(53.3) 7(46.7)	 0.72 0.68

BMI (kg/m^2) Minimum Maximum Mean ± SD	 23 29 26.3 ± 1.62	 22 28.5 25.6 ± 1.82	 0.42
Associated comorbidities* Dm HTN COPD ESKD CVD	 5 (33.3) 7 (46.7) 4 (26.7) 0 1 (6.7)	 6(40) 6(40) 3(20) 1(6.7) 0	 0.81 0.57 0.39 0.2 0.4
Preoperative echocardiography EF Aortic stenosis Aortic regurge Double lesion	 58.5 ± 6.1 6 (40) 8 (53.3) 1 (6.7)	 56.4 ± 5.3 6 (40) 7 (46.7) 2 (13.3)	 0.85 0.72 0.44 0.75
* frequency (percentage)			

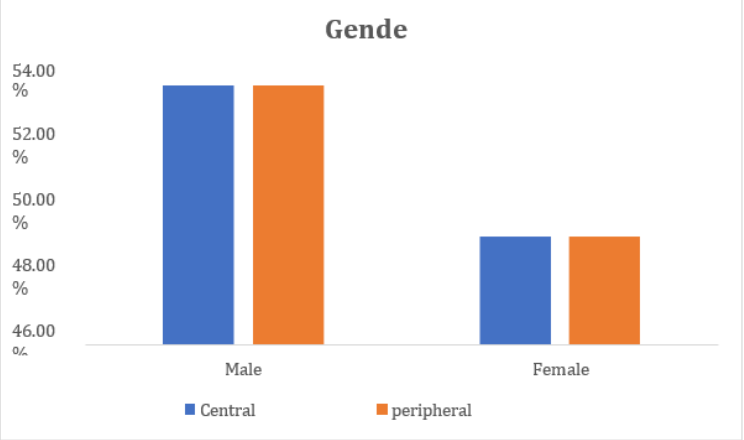

Figure (5): Gender distribution among included patients.

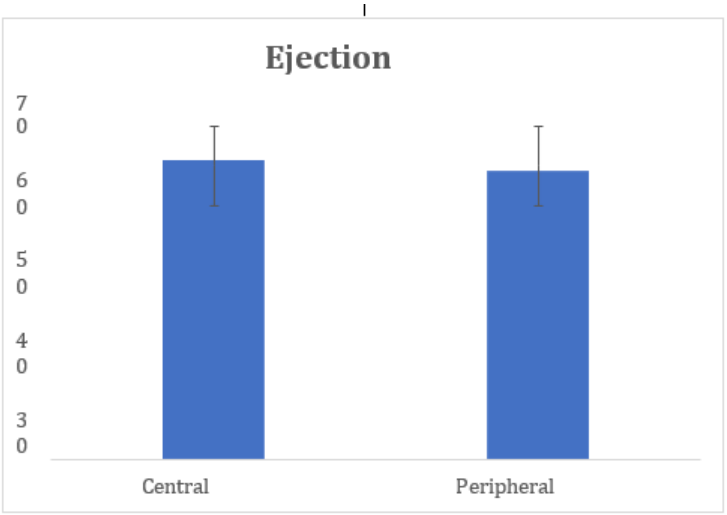

Figure (6): Ejection fraction among included patients.

Intraoperative Findings:
All patients underwent mini-sternotomy aortic valve replacement. The mean bypass time was 102.9 ± 14.2 minutes (range: 85–150), and the mean ischemic time was 80.3 ± 13.7 minutes (range: 59–110).

Patients were divided into two equal groups based on cannulation technique:

- **Group A:** Central venous cannulation (15 patients).
- **Group B:** Percutaneous peripheral femoral venous cannulation (15 patients).

For Group A, the commonly used cannula was 34/46F (53.3%), while Group B predominantly used 25F multistage cannulae (80%). About 33.3% of peripheral cases required vacuum-assisted drainage, and 13.3% required additional central venous access for inadequate drainage.

No cases required conversion to full sternotomy. The mean wound length was significantly shorter in the peripheral group (6.73 ± 1.12 cm) compared to the central group (9.8 ± 0.98 cm, *p = 0.003*).

Although bypass and ischemic times were slightly longer in the peripheral group, the differences were not statistically significant (p = 0.727 and p = 0.451, respectively) (Table 2).

Table (2): Difference between study groups concerning operative findings

	Central Venous cannulation (n=15)	**Peripheral Venous cannulation (n=15)**	**P value**
Cannula Size	32/40F 2(13.3) 34/46F 8(53.3) 36/51F 5(33.3)	23F 3(20) 25F 12(80)	NA
Bypass time (minute)	101.93 ± 10.31	103.8 ± 17.74	0.727 T
Ischemic time (minute)	78.33 ± 15.02	82.2 ± 12.55	0.451 T
Need for vaccium assisted drainage	NA	5(33.3)	0.001 F
Need for full sternotomy opening	0	0	1.00 F
Length of wound (cm)	9.8 ± 0.98	6.73 ±1.12	0.003 T
T; Independent sample t test. F; Fisher exact test. NA; Not Available			

Table (3): Operative findings among included patients (30 patients)

Variable	**Mean**
Bypass time (minute) Minimum Maximum Mean ± SD	85 150 102.87 ± 14.2
Ischemic time (minute) Minimum Maximum Mean ± SD	59 110 80.27 ± 13.7

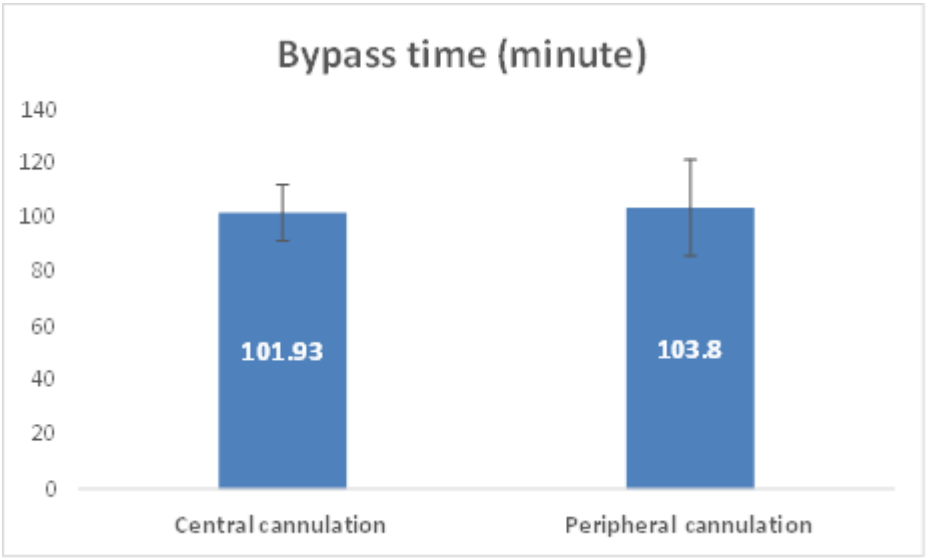

Figure (7): Difference between study groups concerning bypass time.

Table (4): Valve sizes used for aortic valve replacement (30 patients)

Valve size	Number of patients
Mechanical SJ Regent 19	4 (13.33%)
Mechanical SJ Regent 21	15 (50%)
Mechanical SJ Regent 23	5 (16.67%)
Mechanical SJ Regent 25	2 (6.67%)
SJ Epic Tissue 21	4 (13.33%)

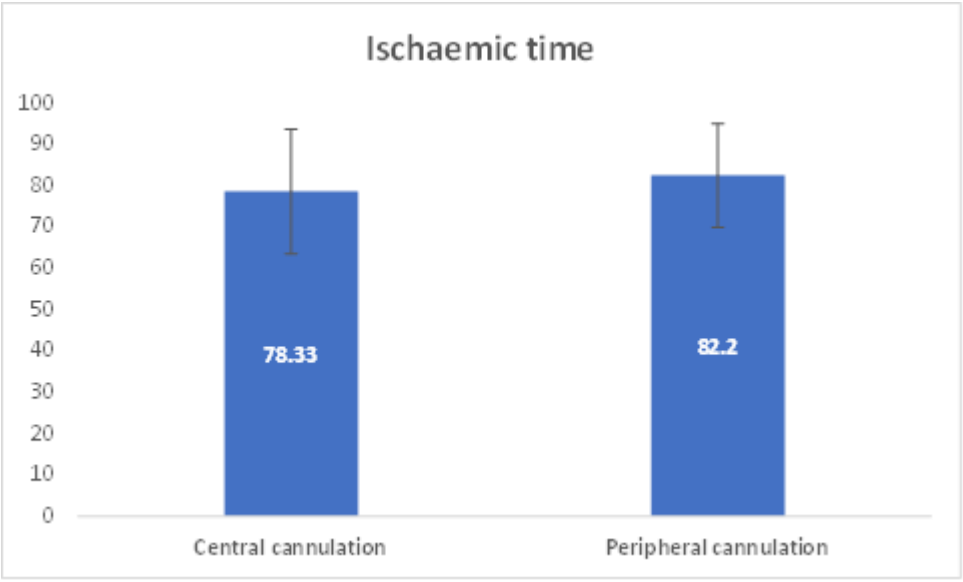

Figure (8): Difference between study groups concerning ischemic time

Postoperative Findings:
We compared between both groups concerning postoperative outcomes and found that:

There was no significant difference between study groups concerning postoperative outcomes. Re-exploration was done among 6.7% of patients (1 patient) in both groups (p=0.759) as shown in table 5.

40% of patients subjected to peripheral cannulation (6 patients) needed postoperative inotropes compared to the other group among whom 46.7% of patients (7 patients) needed inotropes, as shown in table 5. (P=1) Of the patients that underwent peripheral cannulation and vacuum assisted drainage, 13.3% of them (2 patients) developed hematuria from hemolysis that resolved in the

ICU course postoperatively, as shown in table 5. (p=0.37)

Table (5): Difference between study groups concerning postoperative outcomes during ICU stay

	Central cannulation (n=15)	Peripheral cannulation (n=15)	P value
Re-exploration	1 (6.7)	1 (6.7)	0.759 F
Femoral bleeding	0	1 (6.7)	NA
Need for inotropes	7 (46.7)	6 (40)	1.00 C
Myocardial infarction	0	0	NA
Stroke	1 (6.7)	0	0.55 F
Hemodialysis	0	1 (6.7)	0.55 F
Hemolysis	0	2 (13.3)	0.37 F
Postoperative Bradyarrythmias	2 (13.3)	1 (6.7)	0.81 F

Regarding mortality, we found that 6.7% of patients (1 patient) subjected to Central cannulation died in comparison to patients among the other group; there were no recorded cases of postoperative mortality in peripheral cannulation group (p=0.483) as shown in table 9. The mortality case was a patient that suffered from a stroke during ICU stay, patient did not regain consciousness and passed away.

Table (6): Difference between study groups regarding mortality and postoperative recovery.

	Central cannulation (n=15)	Peripheral cannulation (n=15)	P value
Mortality	1(6.7)	0	0.483 F
Average duration of ICU stay in days	2.8±1.3	3.5±2.1	0.66
Average duration of hospital stay in days	7.5±2.9	8.1±4.3	0.78
C; Chi square test. F; Fisher exact test. NA; Not applicable			

Regarding postoperative echocardiography findings, we found that there was no significant difference between study groups concerning postoperative ejection fraction (p=0.336) as shown in table 7.

We also found no recorded cases of postoperative Paravalvular leak among patients in both groups.

We also found no significant difference between patients in both groups concerning gradients across the prosthetic valves (p=0.727) as shown in table 7. Of the 15 patients that underwent central venous cannulation, 13.3% of patients (2 patients) developed severe pericardial effusion, 1 of which underwent therapeutic tapping and the other underwent surgical exploration through left anterior thoracotomy due to poor anterior access by pericardiocentesis as the collection was septated posterolateral.

Table (7): Difference between study groups concerning postoperative echocardiography findings

	Central cannulation (n=15)	Peripheral cannulation (n=15)	P value
EF	58.53 ± 6.14	56.83 ± 5.33	0.336 T
Paravalvular leak	0	0	NA

Gradient across valve	11.93 ± 4.04	12.54 ± 2.04	0.727 T
Pericardial Effusion	2 (13.3)	0	0.093 F
T; Independent sample t test. NA; Not applicable			

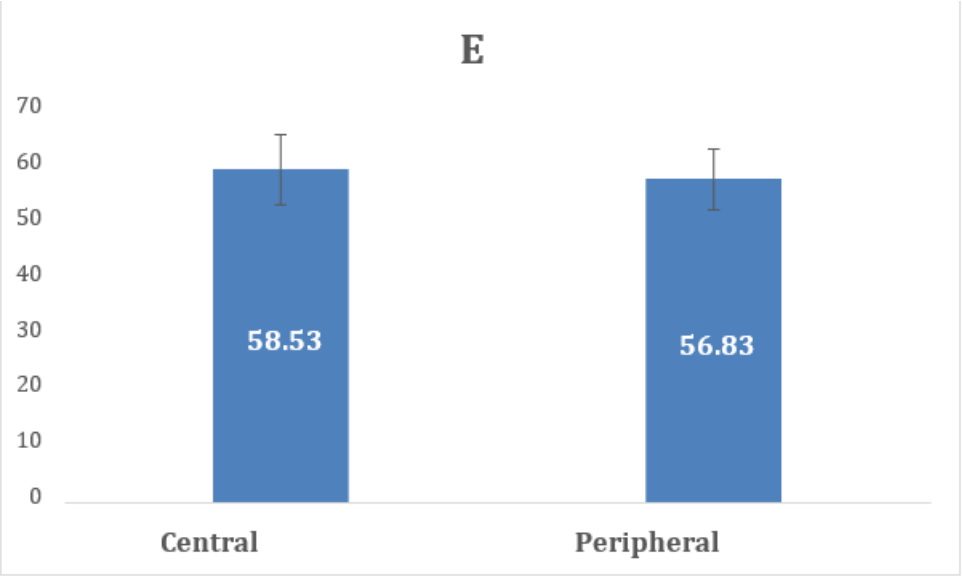

Figure (9): Postoperative EF among patients subjected to both central and peripheral cannulation.

DISCUSSION

Minimally invasive cardiac surgery (MICS) has revolutionized cardiac care by providing effective surgical outcomes with reduced trauma, blood loss, and recovery time compared to full sternotomy. Within MICS, minimally invasive aortic valve replacement (MIAVR) is now the preferred approach in many centers globally [4].

Advances in technology, imaging, and surgical instrumentation have enabled surgeons to perform these complex operations through smaller incisions while ensuring optimal safety. A key element influencing success in MICS is the cannulation strategy, which affects visibility, venous drainage, and procedural safety [5].

This study aimed to compare central versus percutaneous femoral venous cannulation during MIAVR through mini-sternotomy in terms of wound length, CPB and ischemic times, hospital stay, and postoperative complications. Thirty patients who underwent MIAVR at Kasr Al Ainy Hospital between July 2024 and January 2025 were enrolled and divided equally into two groups based on venous cannulation type: central (Group A) and peripheral femoral (Group B).

The mean cardiopulmonary bypass (CPB) time was 102.87 ± 14.2 minutes, within the range reported in similar studies. Del Giglio et al. (2018) found a mean CPB time of 61.0 ± 21.0 minutes in 502 MIAVR cases, while Bruno et al. (2019) observed 93 ± 26 minutes in 120 patients. Longer durations were noted by Sicim and Çaynak (2024) (139.5 ± 30.4 min) and Zallé et al. (2021) (median 131 min). Variations in CPB time across studies likely reflect differences in patient selection, valve pathology, and surgeon experience. [6].

In the present study, cannula size selection was individualized according to patient BMI, a critical factor for adequate venous drainage. High BMI can increase venous return resistance, influencing both cannula performance and postoperative outcomes [7].

Obese patients often face greater surgical risk, highlighting the need for careful cannulation planning to ensure optimal flow dynamics and minimize complications [8].

Vacuum-assisted venous drainage (VAVD) was used in 33.3% of femoral cases to overcome inadequate drainage, higher than the 6% reported by Sicim and Çaynak (2024). The increased use in our series may reflect patient body habitus or smaller cannula sizes. Conversion to full sternotomy was not required, indicating that both approaches were feasible and safe in experienced hands, consistent with Nakajima et al. (2019). Two femoral cases (13.3%) required additional central cannulation due to insufficient drainage, similar to Chan et al. (2012), who advocated selective use of bicaval cannulation when needed [9].

Postoperative outcomes were favorable and comparable between groups. Re-exploration for bleeding occurred in one patient per group (6.7%), consistent with Nakajima et al. (2019). Sternal wound infection occurred in 6.7% of patients in both groups, comparable to the low rates reported by Sicim and Çaynak (2024) and Zallé et al. (2021). Pacemaker implantation was required in 6.7% of cases due to heart block, within the range of 1.5–6.9% reported in previous [10].

Neurological and cardiac outcomes were excellent, with only one stroke (3.3%) in the central group and no myocardial infarction. Similar studies have shown stroke incidences between 0–3% and no increase in risk associated with cannulation type [11].

Local vascular complications were limited to 13.3% of femoral patients who experienced minor groin bleeding or hematoma, with one case leading to superficial wound infection. These rates align with Lamelas et al. (2017), who reported 6.6% groin seroma and 6.65% pseudoaneurysm [8].

Femoral vein injury was rare (6.7%), though such injuries can lead to serious complications like compartment syndrome. Two patients (13.3%) developed transient hematuria due to hemolysis from VAVD, a known risk during CPB [12].

Mortality was 3.3%, similar to previous MIAVR studies showing rates between 1.7% and 3.9%. Brown et al. (2009) confirmed in a meta-analysis that mini-sternotomy can be performed safely without increasing major complications [13].

ICU stay averaged 2.8 ± 1.3 days (central) and 3.5 ± 2.1 days (femoral), comparable to other MIAVR reports. Hospital stay averaged 7.5 ± 2.9 vs. 8.1 ± 4.3 days, respectively, also consistent with the literature. While some studies (Kirov et al., 2024; Saeed et al., 2022) reported shorter hospital stays with percutaneous approaches, our findings showed no significant difference, likely reflecting similar operative efficiency and postoperative recovery in both groups. [14].

The central group showed longer incision length (9.8 ± 0.98 cm vs. 6.73 ± 1.12 cm, $p = 0.003$), confirming the cosmetic advantage of femoral cannulation. Nakajima et al. (2019) reported comparable incision lengths when both arterial and venous cannulas were inserted via separate small incisions, while Kale & Ramalingam (2018) demonstrated acceptable results with 6–7 cm incisions [15].

No significant differences were detected between groups in postoperative stroke, re-exploration, or arrhythmia rates, consistent with Nakajima et al. (2019) and Saadat et al. (2016). LaPietra et al. (2014) further confirmed that stroke incidence in MICS is more related to de-airing techniques than the cannulation approach [16].

In summary, both central and femoral venous cannulation are safe and effective in MIAVR through mini-sternotomy. Femoral cannulation offers smaller incision size, excellent exposure, and equivalent clinical outcomes. With proper patient selection, BMI-based cannula sizing, and meticulous technique, either strategy can be used safely without compromising operative efficiency or patient recovery.

CONCLUSION

Percutaneous peripheral femoral cannulation provides a safe alternative to central venous cannulation for cardiopulmonary bypass with a smaller incision length. When comparing central and femoral venous cannulation, we found no significant difference in the postoperative complication rates and overall mortality.

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