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Results of Local and General Anesthesia in Patients Undergoing Elective Endovascular Abdominal Aortic Aneurysm Repair (EVAR): A Single Center Experience

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Abstract

Objectives: This study aimed to compare the perioperative and postoperative outcomes of elective endovascular abdominal aortic aneurysm repair (EVAR) under general anesthesia (GA) and local anesthesia (LA).

Materials and Methods: This retrospective study included 96 patients who underwent elective EVAR at a single center. The patients were divided into two groups based on the type of anesthesia administered: 48 patients in the GA group and 48 patients in the LA group. Data on demographic characteristics, perioperative factors (such as operation time, blood loss, and contrast volume), and postoperative outcomes (including intensive care unit stay, hospital stay, and complications) were collected and compared between the two groups. The primary focus was on evaluating differences in the operative time, length of hospital stay, and incidence of postoperative complications between the GA and LA.

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Abstract

Results: The total operation time was shorter in the LA group (124.1±22.7 minutes) than in the GA group (136.2±35.3 minutes, p=0.041). The LA group also exhibited significantly lower blood loss (139.5±11.2 mL vs. 181.9±5.1 mL, p<0.001) and used less contrast volume (86.9±19.6 mL vs. 123.0±26.6 mL, p<0.001). Pulmonary complications were more frequent in the GA group (54.2% vs. 10.4%, p<0.001), whereas the LA group had a higher percentage of patients with no complications (50.0% vs. 20.8%, p=0.003). The length of hospital stay was also shorter in the LA group (4.7±0.8 days) than in the GA group (8.7±4.4 days, p<0.001).

Conclusion: LA during EVAR offers significant advantages over GA, including reduced pulmonary complications, shorter operation times, and a shorter length of hospital stay. These findings suggest that LA is a safer and more efficient option for patients undergoing EVAR, particularly those at high risk of pulmonary complications. Further prospective studies are necessary to confirm these results and to guide anesthesia management strategies for EVAR.

Keywords: Anesthesia, endovascular, EVAR, general anesthesia, local anesthesia

Introduction

Endovascular abdominal aortic aneurysm repair (EVAR) has revolutionized the management of abdominal aortic aneurysms, offering a minimally invasive alternative to open surgical repair[1]. The use of EVAR has significantly reduced the perioperative morbidity and mortality associated with aneurysm repair, particularly in patients at high risk for open surgery[2]. However, the choice of anesthesia-whether local or general-remains a critical factor that can influence the outcomes of the procedure. Local anesthesia (LA) is frequently considered in EVAR given its potential to reduce the physiological stress associated with anesthesia, particularly in patients with significant comorbidities[3]. This approach can decrease the risk of hemodynamic instability, minimize respiratory complications, and shorten recovery times, thereby facilitating a faster return to baseline activities[4]. Despite these advantages, LA may pose challenges in terms of patient comfort and procedural duration, especially in complex cases. General anesthesia (GA), on the other hand, provides superior control over airway management and patient immobility, which can be crucial during intricate or prolonged procedures[5]. Although this method ensures a controlled environment and may enhance procedural success, it is associated with risks, particularly in patients with compromised cardiopulmonary function[6]. The physiological impact of GA, including potential cardiovascular stress and prolonged recovery periods, requires careful consideration when selecting the most appropriate anesthetic technique for each patient.

The purpose of this study was to compare the outcomes of local versus GA in patients undergoing elective EVAR at our institution. By examining these results, this study aims to provide insights into the benefits and drawbacks of each anesthetic approach, ultimately guiding the selection of the most suitable anesthesia strategy for different patient profiles.

Materials and Methods

This study was conducted at the Tertiary Training and Research Hospital after receiving approval from the Clinical Research Ethics Committee (approval no.: 2024-03-12, date: 19.02.2024). A total of 96 patients were retrospectively included in the study, spanning a 10-year period. The current study focused on patients who underwent elective endovascular EVAR with either LA or GA.

Patient Selection and Data Collection

Patients who underwent EVAR were retrospectively reviewed, and data were collected regarding the type of

anesthesia (LA) used during the procedures. Demographic data, including age, gender, weight, height, body mass index (BMI), and presence of comorbidities, such as diabetes mellitus, chronic obstructive pulmonary disease (COPD), peripheral artery disease, and coronary artery disease (CAD), were recorded. Additionally, intraoperative parameters such as the type of anesthesia, fluids administered, use of vasodilators (e.g., nitroglycerin), vasopressors (e.g., ephedrine), atropine requirements, arterial and central venous catheterization, duration of surgery, additional surgical interventions, complications, intensive care unit (ICU) stay, and overall hospital stay were documented.

Inclusion and Exclusion Criteria

Patients were included in the study if they met certain criteria, including an abdominal aortic diameter greater than 50 mm for women and greater than 55 mm for men. Additionally, the aneurysm should have originated below the renal arteries, and there should be no occlusion in the iliac arteries. The study also required that patients were willing to undergo surgery, were aged between 50 and 85 years, and did not require any additional abdominal surgery. Patients were excluded from the study if their abdominal aortic diameter was 50 mm for women or 55 mm for men. The exclusion criteria also included aneurysms not originating below the renal arteries, presence of occlusion in the iliac arteries, refusal to undergo surgery, occurrence of abdominal aortic rupture, an age below 50 or above 85 years, and necessity for additional abdominal surgery.

Surgical Procedure

Both femoral arteries were exposed via bilateral groin incisions. Although it is possible to perform the procedure via a single groin incision with percutaneous access to the contralateral limb in certain systems, bilateral femoral exploration is preferred due to the frequent occurrence of vascular complications in EVAR, allowing for more controlled access. After exposing the femoral arteries, a 6- or 7-Fr sheath was inserted into each artery using the Seldinger technique. The decision on which side to deploy the main body and contralateral limb was based on the iliac artery diameters and tortuosity, with the main body typically inserted from the wider, less tortuous iliac artery. A guidewire was advanced, and a marked pigtail catheter was positioned above the aneurysmal segment to visualize the relationship of the aneurysm to the renal and iliac arteries using angiography. Subsequently, the main body of the graft was deployed, followed by the placement of the iliac limbs using the same technique. If necessary, extension grafts were placed in the iliac limbs. A final angiogram was performed to check for any endoleak, which was managed according to its type. In all cases, the graft was successfully opened in the desired location without complications, regardless of the type of anesthesia used. There were no cases of incorrect graft deployment. Typically, femoral artery repair is performed using a 6.0 Prolene suture. In cases of significant atheromatous plaque, the femoral artery is repaired using an interposition with a polytetrafluoroethylene graft. When the iliac artery dissection occurred, the EVAR graft was extended by placing another limb of the graft into the affected side. The EVAR graft was extended to cover the dissected iliac artery.

Postoperatively, all patients were admitted to the cardiovascular surgery intensive care unit, and on the first day, they received 4×1 cc IV heparin. In the following days, patients were administered 100 mg of acetylsalicylic acid daily.

Anesthesia Management

Ninety-six patients participated in the study. All patients underwent standard monitoring with electrocardiography and pulse oximetry. Intravenous cannulation was performed, and appropriate crystalloid solutions were infused. Invasive arterial blood pressure monitoring was achieved via right radial artery catheterization. For general anesthesia, propofol (2 mg/kg), fentanyl (1-2 µg/kg), and rocuronium (0.6 mg/kg). After endotracheal intubation, patients were maintained on mechanical ventilation with tidal volumes of 6-8 ml/kg, fresh gas flow of 2 L/min, and an Fraction of inspired

oxygen of 50% using oxygen and air. The target partial pressure of carbon dioxide was maintained between 35 and 42 mm Hg. Anesthesia was maintained with sevoflurane (0.8-1.1% minimum alveolar concentration) and remifentanil infusion (0.02-2 µg/kg/min). Central venous catheterization was performed using the Seldinger technique in the internal jugular vein, and a bladder catheter was placed for urine output monitoring.

In patients who underwent LA with sedation, the same invasive procedures and monitoring were performed. Sedation was adjusted to achieve a Ramsey sedation score of 4-5, with midazolam (0.03 mg/kg) and fentanyl (0.5 µg/kg) administered intermittently. LA infiltration with lidocaine was administered to the groin region at the incision site. At the beginning of the procedure, 5000 U of heparin was administered intravenously, and anticoagulation was monitored using the activated clotting time (ACT) to maintain ACT at twice the baseline level. Hemoglobin (Hb) levels were maintained above 10 g/dL with replacement therapy as needed.

A combination of lidocaine and bupivacaine was used for LA. Lidocaine, with its rapid onset but shorter duration, was mixed with bupivacaine, which has a slower onset but longer duration of action, in equal volumes. Sodium bicarbonate (1 mL of 8.4% sodium bicarbonate per 10 mL of local anesthetic) was added to the solution to reduce the onset time and burning sensation. The addition of adrenaline extended the anesthesia duration and reduced systemic side effects, although adrenaline was avoided in cases in which its use might induce hypertension (HT) or other adverse effects. We selected LA for patients with pulmonary diseases (such as asthma, COPD), and those with significant comorbidities. This decision was made to reduce mortality and morbidity risks.

The dose limitations of the two anesthetics were independent of each other. The FDA-recommended dose of lidocaine is 7 mg/kg, with a reported maximum dose range of 200-300 mg. The maximum bupivacaine dose was 175 mg. When combined with adrenaline, these values can be increased to 500 and 225 mg, respectively. The maximum doses of both agents can be used together, providing flexibility for bilateral repair. Diluting the agents with saline in a 1:1 ratio also improved the dosing flexibility. Before the initiation of LA, non-invasive blood pressure, electrocardiography, and oxygen saturation monitoring were performed. For optimal surgical conditions, intravenous sedation was added to LA using appropriate doses of midazolam and fentanyl.

Statistical Analysis

The statistical analysis of the data obtained in this study was performed using the SPSS (Statistical Package for the Social Sciences) version 27.0 software. Continuous variables are expressed as mean ± standard deviation, and categorical variables are presented as numbers and percentages (%). The normality of parameters was assessed using the Kolmogorov-Smirnov test. For the comparison of two groups, the Independent Sample t-test was used for normally distributed parameters, while the Mann-Whitney U test was applied for non-normally distributed parameters. A p-value 0.05 was considered statistically significant. The analyses were conducted by comparing the GA and LA groups.

Results

The BMI was significantly higher in the GA group (29.1±3.9) compared to the LA group (27.6±3.6), with a p-value of 0.048, indicating statistical significance. Additionally, there was a higher prevalence of COPD in the LA group (35.4%) than in the GA group (18.8%), with a p-value of 0.066, suggesting a trend toward significance. No statistically significant differences were observed in age, gender, HT, DM, dyslipidemia, pulmonary arterial hypertension, CAD, chronic renal failure, or smoking status between the two groups (Table 1).

There were no statistically significant differences between the general and LA groups regarding preoperative and postoperative Hb levels, preoperative and postoperative creatinine levels, aneurysm sac diameter, neck diameter, or neck length. However, the neck angle in the right-left direction was significantly

greater in the LA group (46.4±7.8 degrees) compared to the GA group (42.6±8.6 degrees), with a p-value of 0.023. Similarly, the neck angle in the anterior-posterior direction was significantly smaller in the LA group (26.7±8.3 degrees) compared to the GA group (30.4±10.9 degrees), with a p-value of 0.002. These differences in neck angles indicate a notable distinction between the groups (Table 2).

The EVAR processing time was significantly longer in the LA group (69.7±15.5 minutes) than in the GA (59.1±23.8 minutes), with a p-value of <0.001. Conversely, the total operation time was shorter in the LA group (124.1±22.7 minutes) than in the GA group (136.2±35.3 minutes), with a p-value of 0.041. Contrast volume usage was significantly lower in the LA group (86.9±19.6 mL) than in the GA group (123.0±26.6 mL), with a p-value of <0.001.

Table 1. Comparison of baseline characteristics between general and local anesthesia groups in patients undergoing EVAR

	General (n=48)	Local (n=48)	p-value
Age (year)	65.2±8.4	66.4±9.7	0.531
Gender	15 (31.3)	20 (41.7)	0.289
BMI (kg/m²)	29.1±3.9	27.6±3.6	**0.048**
HT	26 (54.2)	23 (47.9)	0.540
DM	18 (37.5)	24 (50.0)	0.217
COPD	9 (18.8)	17 (35.4)	0.066
Dyslipidemia	22 (45.8)	26 (54.2)	0.414
PAH	4 (8.3)	7 (14.6)	0.336
CAD	3 (6.3)	6 (12.5)	0.294
CRF	4 (8.3)	2 (4.2)	0.399
Smoke	30 (62.5)	23 (47.9)	0.151

Values are shown as mean ± standard deviation or number (Percentage). Statistically significant results are presented in bold. BMI: Body mass index, HT: Hypertension, DM: Diabetes mellitus, COPD: Chronic obstructive pulmonary disease, PAH: Peripheral artery disease, CAD: Coronary artery disease, CRF: Chronic renal failure

Table 2. Comparison of perioperative hematologic and anatomical parameters between general and local anesthesia groups in patients undergoing EVAR

	General (n=48)	Local (n=48)	p-value
Preop Hb (gr/dL)	12.40±1.12	12.41±0.86	0.935[a]
Postop Hb (gr/dL)	11.24±1.51	11.36±1.2	0.687[a]
Preop Cr (mg/dL)	1.00±0.18	0.96±0.16	0.266[b]
Postop Cr (mg/dL)	1.23±0.55	1.06±0.27	0.454[b]
Aneurism sac diameter (cm)	6.5±0.7	6.5±0.6	0.751[a]
Neck diameter (cm)	2.1±0.2	2.1±0.2	0.523[b]
Neck length (cm)	3.4±0.7	3.2±0.6	0.067[a]
Neck angle (R-L degree)	42.6±8.6	46.4±7.8	**0.023[a]**
Neck angle (A-P degree)	30.4±10.9	26.7±8.3	**0.002[b]**

Values are shown as mean ± standard. Statistically significant results are presented in bold. [a]Independent t-test, [b]Mann-Whitney U test. Preop Hb: Preoperative hemoglobin (grams per deciliter) Postop Hb: Postoperative hemoglobin (grams per deciliter). Preop Cr: Preoperative creatinine (milligrams per deciliter), Postop Cr: Postoperative creatinine (milligrams per deciliter), Aneurism sac diameter: Diameter of the aneurysm sac (centimeters), Neck diameter: Diameter of the aneurysm neck (centimeters), Neck length: Length of the aneurysm neck (centimeters), Neck angle (R-L degree): Right-left degree angle of the aneurysm neck, neck angle (A-P degree): Anterior-posterior degree angle of the aneurysm neck

Blood loss was also significantly lower in the LA group (139.5±11.2 mL) than in the GA group (181.9±5.1 mL), with a p-value of <0.001. The total intensive care time was significantly shorter in the LA group (1.3±0.6 days) compared with the GA group (2.5±1.5 days), with a p-value of <0.001. Similarly, hospitalization duration was significantly shorter in the LA group (4.7±0.8 days) than in the GA group (8.7±4.4 days), with a p-value of <0.001 (Table 3).

There were no intraoperative ruptures in either group. Postoperative pain management predominantly involved opioid use, with slightly higher usage in the LA group (72.9%) than in the GA group (62.5%), although this difference was not statistically significant. In terms of postoperative complications, acute renal failure was significantly more common in the GA group (25.0%) than in the LA group (10.4%), with a p-value of 0.041. Pulmonary complications were also significantly more frequent in the GA group (54.2%) than in the LA group (10.4%), with a p-value of <0.001. Infectious complications were more prevalent in the GA group (45.8%) than in the LA group (25.0%) (p=0.033). There were no significant differences between the groups in terms of hospital mortality, permanent or transient neurological deficits, need for dialysis, distal organ malperfusion, cerebrovascular accident, myocardial infarction, stent migration, spinal cord ischemia, iliac artery dissection, lower extremity embolism, or ischemic colitis. Finally, the incidence of no complications was significantly higher in the LA group (50.0%) than in the GA group (20.8%), with a p-value of 0.003. When spinal cord ischemia developed, the patient's systolic blood pressure was maintained at 100 mmHg with the use of inotropic support if necessary. Upon follow-up, spinal cord ischemia regressed in both patients (Table 4).

At the first postoperative month, computed tomography (CT) angiography results showed that the majority of patients had normal findings, with 87.2% in the GA group and 95.8% in the LA group, although this difference was not statistically significant (p=0.229). There were two cases of Type 1 endoleak in the GA group and no cases in the LA group. Femoral region infections were slightly more common in the GA group (8.5%) than in the LA group (4.2%). By the sixth postoperative month, normal findings were observed in 91.5% and 97.9% of the general and LA groups, respectively, with no statistically significant difference (p=0.530). There was one case each of Type 1 endoleak in both groups, one case of Type 3 endoleak and one pseudoaneurysm in the GA group, and one exitus, all of which were absent in the LA group. At the 12th postoperative month, 97.9% of patients in the GA group and 100% of patients in the LA group had normal CT angiography findings, with no statistically significant difference between the groups (p=0.893) (Table 5).

Table 3. Comparison of procedural and postoperative outcomes between general and local anesthesia groups in patients undergoing EVAR

	General (n=48)	Local (n=48)	p-value
EVAR fluoroscopy time (min)	59.1±23.8	69.7±15.5	**<0.001**[b]
TOTAL operation time (min)	136.2±35.3	124.1±22.7	**0.041**[b]
Contrast volume (mL)	123.0±26.6	86.9±19.6	**<0.001**[a]
Blood loss (mL)	181.9±5.1	139.5±11.2	**<0.001**[a]
Primary endoleak	0.2±.0.7	0.1±0.3	0.165[b]
Total ıntensive care time (day)	2.5±1.5	1.3±0.6	**<0.001**[b]
Hospitalisation (day)	8.7±4.4	4.7±0.8	**<0.001**[b]

Values are shown as number (percent). Statistically significant results are presented in bold. EVAR: Endovascular aneurysm repair, min: Minutes, mL: Milliliters

Table 4. Comparison of intraoperative and postoperative complications between general and local anesthesia groups in patients undergoing EVAR

		General (n=48)	Local (n=48)	p-value
Rupture during operation		0 (0.0)	0 (0.0)	1.000
Postoperative pain managment	Opioide	30 (62.5)	35 (72.9)	0.399
	Paracetamol	13 (27.1)	11 (22.9)	
	NSAID	5 (10.4)	2 (4.2)	
Hospital mortality		1 (2.1)	0 (0.0)	0.315
Permanent neurological deficit		0 (0.0))	1 (2.1)	0.315
Transient neurological deficit		6 (12.5)	5 (10.4)	0.749
ARF		12 (25.0)	5 (10.4)	**0.041**
Need for dialysis		1 (2.1)	1 (2.1)	1.000
Pulmoner complication		26 (54.2)	5 (10.4)	**<0.001**
Infektif complication		22 (45.8)	12 (25.0)	**0.033**
Distal organ malperfusion		1 (2.1)	3 (6.3)	0.132
CVA		1 (2.1)	1 (2.1)	1.000
Endoleak		1 (2.1)	1 (2.1)	1.000
MI		1 (2.1)	1 (2.1)	1.000
Stent migration		4 (8.3)	1 (2.1)	0.068
Spinal cord ischemia		2 (4.2)	0 (0.0)	0.153
Iliac artery dissection		1 (2.1)	1 (2.1)	1.000
Lower extremity embolism		4 (8.3)	2 (4.2)	0.399
Ischemic colitis		1 (2.1)	1 (2.1)	1.000
No complications		10 (20.8)	24 (50.0)	**0.003**

Values are shown as number (percent). Statistically significant results are presented in bold. NSAID: Non-steroidal anti-ınflammatory drug, ARF: Acute renal failure, CVA: Cerebrovascular accident, MI: Myocardial infarction

Table 5. Comparison of postoperative CT angiography findings at 1, 6, and 12 months between general and local anesthesia groups in patients undergoing EVAR

		General (n=48)	Local (n=48)	p-value
Postop 1st month CT angiography	Normal	41 (87.2)	46 (95.8)	0.229
	Type 1 endoleak	2 (4.3)	0 (0.0)	
	Femoral region infection	4 (8.5)	2 (4.2)	
Postop 6th month CT angiography	Normal	43 (91.5)	47 (97.9)	0.530
	Type 1 endoleak	1 (2.1)	1 (2.1)	
	Type 3 endoleak	1 (2.1)	0 (0.0)	
	Pseudoaneurysm	1 (2.1)	0 (0.0)	
	Exitus	1 (2.1)	0 (0.0)	
Postop 12th month CT angiography	Normal	47 (97.9)	48 (100.0)	0.893

Values are shown as number (percent). CT: Computed tomography

Discussion

Significant differences were identified between patients who underwent GA and those who received LA. Notably, although the procedure time was longer in the LA group, the total surgery time was shorter in the GA group. Additionally, the amount of contrast agent used and blood loss were significantly lower in the LA group. Moreover, ICU and hospital stay were significantly shorter in the LA group than in the GA group. Pulmonary complications and infection rates were higher in the GA group, whereas the rate of patients without complications was higher in the LA group. These findings suggest that LA is a less invasive option during the perioperative period, potentially reducing the risk of complications and improving patient outcomes.

The 2021 study by Liu et al.[7] compared the outcomes of EVAR patients undergoing GA, regional anesthesia (RA), and LA, revealing similarities and differences with our findings. In Liu et al.[7] study, the procedure time was significantly shorter in the LA group compared with the GA group; this contrasts with our finding that the procedure time was longer in the LA group. However, both studies found that total surgery time was shorter in the LA group, suggesting that LA may expedite postoperative recovery. Additionally, both studies reported shorter hospital stays in the LA group. Regarding pulmonary complications, Liu et al.[7] found a lower risk in the LA group, consistent with our findings, whereas pulmonary complications were more prevalent in the GA group. In conclusion, Liu et al.[7] study supports our findings that LA may offer advantages in EVAR procedures. The 2022 meta-analysis by Lei et al.[7] compared GA and LA in EVAR and showed that LA may be more advantageous in reducing perioperative mortality in hemodynamically stable patients[8]. This finding is also consistent with our study, in which lower pulmonary complication rates were observed in the LA group. Lei et al.[8] study further supports the notion that LA may reduce pulmonary complications, making it a safer option during the perioperative period. However, the lack of a significant difference in complication rates between GA and LA emphasizes the need for careful selection of the anesthesia method based on patient characteristics.

In the 2018 study by Noh et al.[9], no significant differences were found between the GA and LA groups regarding endoleak incidence, length of hospital stay, and 30-day clinical outcomes. This result contrasts with some aspects of our study; for example, the LA group had a shorter length of hospital stay and fewer pulmonary complications. Although Noh et al.[9] findings suggest similar short-term outcomes between GA and LA, our results indicate that LA may offer certain advantages. In a 2019 study by Harky et al.[10], a comparison of anesthetic techniques used during EVAR was conducted, including three systematic reviews with meta-analyses. One study found statistically significant advantages in mortality, morbidity, and length of hospital stay, thereby favoring local regional anesthesia. However, another study showed no significant mortality benefit from LA. These findings align with our study, in which we also found shorter hospital stays and lower complication rates in the LA group. However, Harky et al.[10] highlighted that some results were not statistically significant, suggesting that heterogeneity among studies may influence outcomes.

A 2019 study by Faizer et al.[11] demonstrated that rEVAR-LA (EVAR performed under LA) was associated with shorter operative times, fewer blood transfusions, lower pulmonary complications, and shorter ICU stays compared to rEVAR-GA (EVAR performed under general anesthesia). Additionally, 30-day and 1-year mortality rates were significantly lower in the rEVAR-LA group than in the rEVAR-GA group. These findings support the advantages of LA as observed in our study and suggest that LA may be more beneficial for the treatment of rAAA. Hajibandeh et al.[12] compared local (LA) and RA with GA in EVAR and found that perioperative mortality was significantly lower in the RA group than in the GA group. The meta-analysis portion of the study also found that LA and RA were associated with lower perioperative mortality and morbidity, as well as shorter hospital stays, compared with GA. These findings align with our study,

in which LA was associated with lower complication rates and shorter hospital stays, further supporting the benefits of LA in EVAR.

Study Limitations

This study has several important limitations. First, our study has a retrospective design, which may introduce certain limitations in data collection and interpretation. Prospective RCTs could provide stronger evidence and enhance the generalizability of our findings. Second, the study was conducted at a single center, which limits the diversity of the patient population and surgical practices. This may restrict the applicability of the results to other centers or broader populations. Third, the choice of anesthesia method in this study was based on patient characteristics and surgeon preference, without randomization. This may have introduced potential bias related to the selection of anesthesia. Lastly, this study did not evaluate long-term outcomes, and there is limited information about the long-term effects of the anesthesia method on patient outcomes. Future studies should aim to address these limitations to obtain more comprehensive and generalizable results.

Conclusion

In conclusion, our study provides significant findings by evaluating the differences between general and LA methods in patients undergoing EVAR. LA offers several advantages, particularly in reducing pulmonary complications, shortening hospital stay, and decreasing total surgery time. However, the procedure time may be longer than that of general anesthesia. LA may be a safer and more effective option, especially in high-risk patient groups, particularly those with pulmonary comorbidities. Nevertheless, the choice of anesthesia method should be individualized, taking into account patient characteristics and surgical requirements. These findings support the preference for LA in EVAR procedures and should be considered in anesthesia management strategies. Future larger-scale prospective studies are essential to confirm these findings and provide clearer guidance on anesthesia management.

Ethics

Ethics Committee Approval: This study was conducted at the Tertiary Training and Research Hospital after receiving approval from the Clinical Research Ethics Committee (approval no.: 2024-03-12, date: 19.02.2024).

Informed Consent: This retrospective study.

Footnotes

Authorship Contributions

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Research Article

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Relation Between Systemic Immune-Inflammation Index and Post PCI Bleeding Risk in STEMI Patients

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Abstract

Objectives: To investigate the relationship between the systemic immune-inflammation index (SII) and bleeding complications in ST-elevated myocardial infarction (STEMI) after percutaneous coronary intervention (pPCI).

Materials and Methods: This retrospective study included 1778 patients who presented with STEMI and underwent pPCI. Patients were divided into two groups: those who developed bleeding and those who did not. The SII values and CRUSADE bleeding score were calculated.

Results: In the group with bleeding complications, the ages were 62 (50-73), and 69.6% were male. Multivariate analysis identified age 1.031(1.015-1.048) - p<0.001, basal creatinine 1.789 (1.366-2.342) - p<0.001, SII 1.163 (1.028-1.315)- p=0.013 as significant predictors of bleeding complications.

Conclusion: The easily calculated SII may help predict bleeding complications in STEMI patients undergoing pPCI.

Keywords: ST elevation myocardial infarction, bleeding, systemic immune-inflammation index

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Introduction

Coronary artery disease (CAD) continues to be a common cause of morbidity and mortality[1]. During and after percutaneous coronary intervention (pPCI), anticoagulant and antiaggregant treatments are necessary[2-4]. This situation presents a risk of bleeding[5]. Various bleeding events, from simple skin ecchymosis to more serious intracranial or gastrointestinal bleeding, can be observed in hospitalized patients with ST-elevated myocardial infarction (STEMI). In particular, as comorbidities and age increase, bleeding complications occur more frequently. Both morbidity and mortality increase due to bleeding, as well as the hospital stay lengthens. In this context, minimizing, preventing, or identifying the risk of bleeding is extremely important[6,7].

To lessen the risk of bleeding, the patient should be evaluated as a whole, considering age and comorbidities, and patient-based, dose-adjusted treatment should be applied. Current guidelines include adjustments in time and dose considering both bleeding-ischemia risk and the patient's clinical condition in dual antiplatelet therapy recommendations[8,9].

The systemic immune-inflammation index (SII) was calculated using neutrophil, lymphocyte, and platelet counts. Many studies have shown its relationship with acute coronary syndromes, CAD, and certain heart rhythm disorders. Additionally, the relationship between the SII and STEMI thrombus load, recurrent myocardial infarction, and short- and long-term mortality has been determined[10-13]. In our study, we aimed to reconnoiter the effect of the SII in predicting bleeding complications in patients hospitalized with a diagnosis of STEMI.

Materials and Methods

Study Population

The study was conducted retrospectively at a single center on 1778 patients who were diagnosed with a diagnosis of STEMI and underwent PCI. The symptoms of the patients were detected within the first 12 hours. At the time of diagnosis, each patient was administered clopidogrel (600 mg) or ticagrelor (180 mg) with aspirin (300 mg) and dose- adjusted heparin in the emergency service before being sent to the laboratory. The diagnosis of STEMI was made according to the latest guidelines of the European Society of Cardiology[14]. Demographic and clinical features, previous medical history, physical examination, laboratory examination, and intervention-related data were obtained from the patient's file and the hospital and national database. Coronary angiography was performed via femoral Access in 90% of the patients and via 10% radial access. Primary PCI was performed in all patients.

Patients with advanced kidney and liver disease, a history of malignancy, and coagulopathy, as well as those who were breastfeeding or pregnant, were not included in the study. The study was conducted according Ankara Etlik City Hospital No. 1 Clinical Research Ethics Committee (approval no.: AEŞH-EK-1-2023-610, date:11.10.2023). The Declaration of Helsinki and was approved by the ethics committee. The study design was retrospective; thus, patient consent was not obtained.

Bleeding complications in patients were noted. Major bleeding was defined as ISTH, a fall in hemoglobin level of 2 g/dL or more, or documented transfusion of at least 2 units of packed red blood cells, (b) involvement of a critical anatomical site (intracranial, spinal, ocular, pericardial, articular, intramuscular with compartment syndrome, retroperitoneal[15]. The CRUSADE bleeding score was calculated using an online calculator[16]. Minor bleeds occurs in many patients, we did not report clinically meaningless bleeding events such as minor nose, gum bleeding, and ecchymoses.

Statistical Analysis

Continuous variables are presented as mean ± standard deviation, whereas categorical variables are presented as percentages. The Kolmogorov-Smirnov test was used to verify the normality of the distribution of continuous variables. The statistical analysis of clinical data between

the two groups consisted of unpaired t-tests for parametric data and Mann-Whitney U test analysis for non-parametric data. Continuous and categorical variables were analyzed using the chi-square test and Student's t-test as appropriate. Two-tailed p<0.05 was accepted as statistically significant. Statistical analyses were performed using SPSS 26.0 (SPSS Inc., Chicago, IL, USA).

Results

A total of 1778 patients were included in the study. In the group with observed bleeding complications (n=112. 6%), the average age was 62 (50-73), and 69.6% were male. In the group without bleeding complications, the mean age was 55 (47-64), and 81.2% were male. In the bleeding group, diabetes and hypertension were significantly higher (p<0.05). Left ventricular ejection fraction values were lower in the bleeding group (p <0.001). Other basal characteristics of the groups are presented in Table 1.

In the bleeding group, peak troponin I, glucose, white blood cell, neutrophil, C-reactive protein, creatinine, neutrophil-to-lymphocyte ratio (NLR), SII, and crusade scores were higher than in the non-bleeding group (p<0.05). The laboratory findings for the patient groups are presented in Table 2.

The most common bleeding complication observed was an access site problem, accounting for 43 (38.4%). The rate of major bleeding was 23 (21.6). Sources of bleeding complications are presented in Table 3. The SII was higher in the bleeding group (Figure 1).

In the multivariate analysis, age 1.031(1.015-1.048, p<0.001), basal creatinine 1.789 (1.366-2.342, p<0.001), SII 1.163 (1.028-1.315, p=0.013) were identified as significant predictors of bleeding complications (Table 4).

Scatter dot plot of the correlation between SII, CRUSADE score showed in Figure 2.

Table 1. Baseline characteristics of patients with STEMI

Variables	Non-bleeding group n=1666	Bleeding group n=112	p-value
Age, years	55 (47-64)	62 (50-73)	<0.001
Male gender, n (%)	1362 (81.2)	78 (69.6)	0.003
Diabetes mellitus, n (%)	369 (22.0)	42 (37.5)	<0.001
Hypertension, n (%)	659 (39.3)	57 (50.9)	0.015
Current smoker, n (%)	932 (55.6)	44 (39.3)	0.001
Dislipidemi, n (%)	672 (40.1)	36 (32.1)	0.097
Previous ASA usage, n (%)	35 (2.1)	2 (1.8)	0.828
Systolic BP, mm Hg	131.17±30.45	129.78±38.26	0.706
Diastolic BP, mm Hg	77.79±18.45	76.39±23.21	0.534
Heart rate, bpm	76.96±15.63	76.69±21.15	0.892
LVEF, %	48.0 (42.0-55.0)	43.0 (35.0-50.0)	<0.001
Contrast volume, mL	270 (210-300)	280 (220-320)	0.136
Anterior MI, n (%)	810 (48.6)	65 (58.0)	0.063
Non-anterior MI, n (%)	856 (51.4)	47 (42.0)	
TIMI thrombus grade, n (%) 1-2 (low) 3 (middle) 4-5 (high)	 101 (6.1%) 466 (28.0%) 1099 (66.0%)	 7 (6.3%) 24 (21.4%) 81 (72.3%)	 0.321 0.330 0.166
ASA loading dose 300 mg, %	1082 (64.9)	106 (94.6)	0.032
Klopidogrel giving loading dose, n (%)	696 (41.8)	49 (43.7)	0.148
Tikagrelor giving loading dose, n (%)	970 (58.2)	63 (56.3)	0.225

ASA: Acetylsalicylic acid, BP: Blood pressure, LVEF: Left ventricular ejection fraction, MI: Myocardial infarction, TIMI: Thrombolysis in myocardial infarction

Table 2. Baseline laboratory findings of patients with STEMI

Variables	Non-bleeding group n=1666	Bleeding group n=112	p-value
Basal troponin I, ng/L	1.98 (0.72-4.56)	2.34 (0.90-6.46)	0.102
Peak troponin I, ng/L	78.0 (36.7-166.0)	120.0 (47.0-244.0)	<0.001
Glucose, mg/dL	125.0 (103.0-163.0)	144.0 (117.5-220.5)	<0.001
Hemoglobin, g/dL	14.0 (13.0-15.0)	13.4 (11.5-14.9)	0.001
eGFR, mL/min/1.73m^2	89.0 (73.0-104.0)	70.5 (51.0-90.0)	<0.001
White blood cell, ×103/µL	12.17±3.62	13.86±4.60	<0.001
Neutrophil, ×103/µL	9.35±3.47	11.01±4.21	<0.001
Lymphocyte, ×103/µL	1.97±1.03	1.89±0.85	0.427
Platelet, ×103/µL	256.4±65.5	261.37±67.90	0.433
Total cholesterol, mg/dL	178.91±43.80	165.08±40.97	0.007
HDL, mg/dL	38.52±12.08	40.39±14.05	0.130
LDL, mg/dL	114.62±38.69	103.12±33.37	0.003
Triglyceride, mg/dL	138.57±92.69	135.21±61.11	0.614
Lipoprotein (a)	24.96±19,33	23.55±32.25	0,834
C-reactive protein, mg/L	13.27±11.84	20.33±17.50	<0.001
Albumin, g/dL	3.7 (3.5-4.0)	3.5 (3.2-4.0)	0.004
Creatinine, mg/dL	0.87 (0.75-1.00)	0.96 (0.80-1.32)	<0.001
NLR	5.00 (3.21-7.85)	6.04 (02-8.74)	0.005
PLR	138. (101.3-199.2)	149.7 (107.6-204.8)	0.489
SII x10^3	1243.9 (777.3-2008.3)	1539.4 (995.7-2381.8)	0.003
CRUSADE score	24.0 (17.0-33.0)	36.0 (23.5-50.0)	<0.001

eGFR: Estimated glomerular filtration rate, HDL: High-density lipoprotein, LDL: Low-density lipoprotein; NLR: Neutrophil-lymphocyte ratio, PLR: platelet-lymphocyte ratio, SII: Systemic immune-inflammation index, *STEMI: ST-Elevation myocardial infarction*

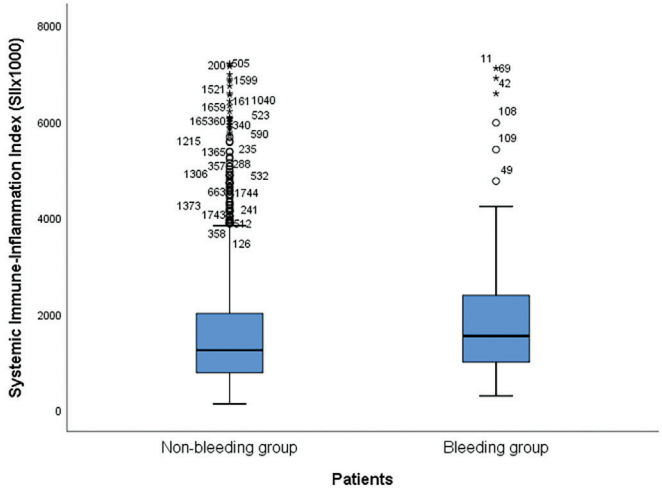

Figure 1. Box plot of the SII according to bleeding and nonbleeding groups

SII: Systemic immune-inflammation index

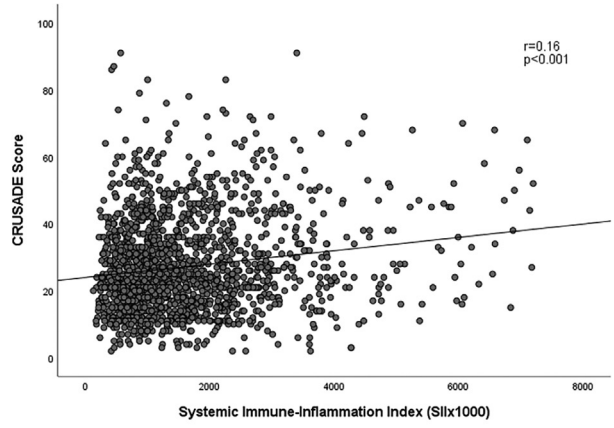

Figure 2. Scatter dot plot of the correlation between SII and CRUSADE scores

SII: Systemic immune-inflammation index

Discussion

In this study, we found that the SII, age, and creatinine levels predicted in-hospital bleeding complications in STEMI patients undergoing PCI. To our knowledge, this study is the first to investigate the relationship between SII and bleeding complications in patients with STEMI.

As is well known, STEMI commonly develops after plaque rupture, requiring emergency treatment. Despite advancements in stent, balloon, and PCI technologies, anti-ischemic and anticoagulant agents are administered to patients before and after the procedure. As a natural consequence of these hemostatic agents, undesired bleeding events are sometimes observed[17]. The most common bleeding complication is access site bleeding, in addition to gastrointestinal, urinary system, cardiac, retroperitoneal, and intracranial bleeding[18-20]. In clinical practice, bleeding is classified as major and minor bleeding. A situation is called major bleeding if it is related to hemodynamic instability, occurs anatomically in a critical area, requires transfusion of 2 units or more erythrocyte suspension, or causes a fall in hemoglobin levels of 2 g/dL or more (if the basal value is known)[21]. It is understandable from this point that bleeding events can lead to life-threatening situations. Additionally, hospitalization time and costs increase because of bleeding, and occurrences of re-infarction and acute thrombosis events are observed because of the interruption or discontinuation of anti-ischemic drugs[22,23]. In this context, it is extremely important to predict and prevent undesired bleeding events.

As patients' creatinine levels increase, bleeding complications also increase. In our study, the creatinine level was significantly higher in the bleeding group. Despite dose adjustments for several drugs with renal excretion in clinical practice, bleeding events can still occur[24]. During PCI in STEMI patients, contrast-induced nephropathy can develop due to the contrast substance given[25]. In addition to dose adjustments, appropriate hydration is extremely important, especially in patients who will take contrast substances for any reason, to prevent contrast-induced nephropathy and carefully use nephropathy-causing drugs carefully[26].

Table 3. Post MI bleeding events (n=112)

Access site, n (%)	43 (38.4)
Urinary system, n (%)	12 (10.7)
Gastro intestinal system, n (%)	36 (31.1)
Intracranial, n (%)	2 (1.8)
Retroperitoneum, n (%)	4 (3.6)
Tamponade, n (%)	1 (0.9)
Other, n (%)	14 (12.5)
Minor, n (%)	89 (79.4
Major, n (%)	23 (21.6)

MI: Myocardial infarction

Table 4. Univariate and multivariate analyses for predictors of post MI bleeding

Variables	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Age	1.040 (1.024-1.056)	<0.001	1.031 (1.015-1.048)	<0.001
COPD	1.322 (0.595-2.934)	0.493		
Creatinine	1.994 (1.491-2.666)	<0.001	1.789 (1.366-2.342)	<0.001
Basal troponin	1.010 (0.991-1.028)	0.302		
Lipoprotein (a)	0.997 (0.966-1.028)	0.832		
TIMI thrombus grade	1.199 (0.854-1.683)	0.294		
Contrast volume	1.002 (0.999-1.004)	0.140		
SII	1.221 (1.063-1.402)	0.005	1.163 (1.028-1.315)	0.013

COPD: Chronic obstructive pulmonary disease, MI: Myocardial infarction, SII: Systemic immune-inflammation index, TIMI: Thrombolysis in myocardial infarction, OR: odds ratio, CI: Confidence interval

With increasing age, fragility also increases, and dose adjustments are made when administering anti-ischemic and anticoagulant drugs. It is no coincidence that age is a component of HAS-BLED scoring. In a study conducted by Franken et al.[27], it was observed that as age increases, bleeding complications increase.

Although the relationship between age and creatinine levels with bleeding has been demonstrated, no study has shown the relationship between SII, which is calculated using neutrophil, lymphocyte, and platelet counts, and bleeding, which can indicate the status of inflammatory, immune, and coagulation cascades. The SII has been found to be related to the development, monitoring, and prognosis of many diseases, particularly those in which inflammation plays a role in pathogenesis. The study by Guzel and Kis[28] investigated the relationship between the SII and the Atherogenic plasma index (AIP) in assessing the severity of coronary lesions through fractional flow reserve measurements. They found that although the SII possessed higher sensitivity, the AIP also significantly predicted the severity of coronary lesions. In a study conducted by Dolu et al.[29], it was shown that the SII is related to a high thrombus load in STEMI patients[30]. Moreover, there are studies that have investigated the SII in estimating short- and long-term mortality in STEMI patients.

In our study, we found that SII can predict bleeding in STEMI patients. The first stage of the hemostatic process involves platelet plug formation after endothelial damage. Subsequently, the coagulation cascade is activated. Platelets are activated in the area of vascular injury to provide the initial hemostatic response by forming a platelet plug to stop bleeding. Injury to the endothelium exposes subendothelial elements that are normally protected from circulating blood, and endothelial cell activation can promote the collection of platelets, other cell types, and procoagulant factors. The activated platelets initiate the initial hemostatic process by developing adhesion, aggregation, secretion, and procoagulant activities. Proinflammatory cytokines can affect platelet formation, activation, and function, leading to bleeding or thrombosis[31].

Many previous studies have shown that the NLR predicts many bleeding events[32]. In this context, the SII contains both platelet count and NLR and may be more guiding in terms of bleeding prediction.

The CRUSADE bleeding score is a tool that predicts bleeding in post-myocardial infarction patients by evaluating the patient's heart rate, systolic blood pressure, hematocrit, creatinine clearance, gender, presence of heart failure symptoms on admission, history of vascular disease, and presence of diabetes mellitus[33]. In our study, we found a positive correlation between SII and the CRUSADE bleeding score. This relationship contributes to the SII's ability to predict bleeding.

Study Limitations

The main limitation of this study is its retrospective nature. The relatively lower number of patients included in the study can also be considered a limitation. A comparison of patients who underwent radial and femoral intervention for bleeding and SII could not be performed due to the lack of sufficient number of patients and data. STEMI is a morbid and fatal disease. Bleeding complications can occur after pPCI in STEMI patients. The SII was higher in the bleeding group. Finally, the easily calculated SII may help predict bleeding complications in patients undergoing pPCI.

Conclusion

The easily calculated SII may help predict bleeding complications in patients undergoing pPCI. This approach may provide additional benefits to clinicians in managing medications and conditions that cause bleeding in this patient group.

Ethics

Ethics Committee Approval: The study was conducted according Ankara Etlik City Hospital No. 1 Clinical Research Ethics Committee (approval no.: AEŞH-EK-1-2023-610, date:11.10.2023). The Declaration of Helsinki and was approved by the ethics committee.

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

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Research Article

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Open Seldinger Technique in 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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Abstract

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

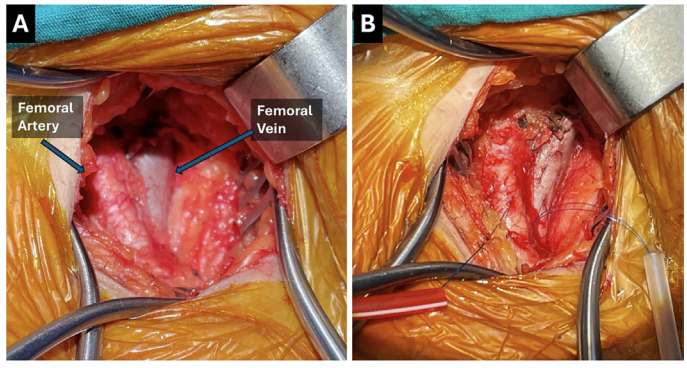

Figure 1. (a) Femoral artery and vein exploration (b) Placement of purse-string suture

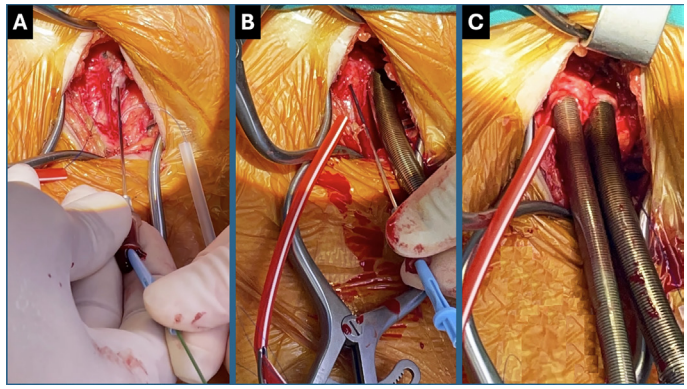

Figure 2. (a) Placement of guidewire through needle with Seldinger technique in femoral vein, (b) application of Seldinger technique in femoral artery, (c) after femoral artery-vein cannulation

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 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.

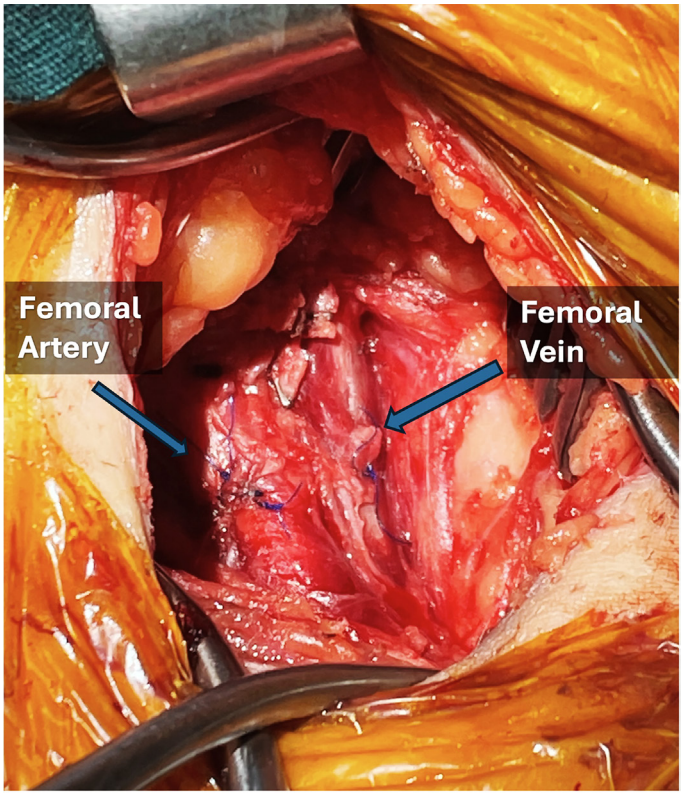

Figure 3. After tying purse-string sutures following decannulation of the femoral artery and vein

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

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

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 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

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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

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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.

Footnotes

Authorship Contributions

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

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Research Article

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Outcomes of Complete Repair of Mixed-Type Total Anomalous Pulmonary Venous Return

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Abstract

Objectives: To retrospectively review 14 cases, describe preoperative imaging, anatomic findings and confirmation at surgery, surgical technique, and outcomes.

Materials and Methods: We describe anatomic variations in mixed-type total anomalous pulmonary venous return and surgical outcomes in a case series from 2 centers. Mixed-type total anomalous pulmonary venous return is classified based on the pattern of pulmonary venous drainage. Type I refers to '2+2' drainage of venous pairs, type II refers to '3+1' and type III refers to all other variants. Six patients (43%) had type I "2+2" drainage; 2 patients had 2 supra-cardiac and 2 cardiac connections, and 4 patients had 2 infra-cardiac connections and 2 cardiac. 4 patients (29%) had type II "3+1" drainage. Three patients had 3 cardiac and 1 supra-cardiac variants and one had a rare supra-cardiac pulmonary venous combination. 4 patients (29%) had type III morphology. 2 patients of them had 3+2 anatomy with 3 supra-cardiac and 2 cardiac connections, both of which included 3 right-sided pulmonary veins. The remaining 2 patients had unique anatomy, one with tri-level attachment to cardiac, supra-cardiac, and infra-cardiac and the last with all supracardiac pulmonary venous drainage but in a "3+1+1" pattern.

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Abstract

Results: In previous publications, mixed-type total anomalous pulmonary venous return has a higher mortality rate, with univariate analysis of mixed-type versus cardiac type with statistically significant hazard ratios of 2.88 in previous study and mortality as high as 42-50%. We achieved improved outcomes, with overall survival of 79% and no intraoperative mortality. Both patients who had complex intracardiac lesions (1 with ventricular septal defect and 1 with tetralogy of fallot) ultimately died. Of the remaining patients, 29% developed pulmonary venous obstruction on echocardiography follow-up with 3 requiring interventions with cardiac catheterization.

Conclusion: Mixed-type total anomalous pulmonary venous return has a wide variety of connections, which contributes to the complexity of planning and surgical correction. Further studies are needed to better understand the different morphologies of the disease.

Keywords: Mixed type, outcome, surgical management, total anomalous pulmonary venous return

Introduction

Total anomalous pulmonary venous return (TAPVR), also referred in literature as total anomalous pulmonary venous connection (TAPVC), provides a wide spectrum of complex anatomic and therapeutic challenges amongst congenital heart disease. An estimated 400 infants (1/10.000 births) are born annually in the United States with TAPVR, an incidence among congenital heart disease of 0.7-1.5%[1,2]. While there may be rare survival to adulthood if un-repaired[3,4], typical median survival if unrepaired is 2 months with 50% mortality in first 3 months of life, thereby demonstrating the urgency of recognition and intervention[4].

TAPVR is classified according to the Darling system developed in 1957 into cardiac, supracardiac, infracardiac, or mixed-type depending on the pattern of pulmonary venous (PV) drainage to the systemic venous circuitry[5]. Cardiac forms have PV return to the coronary sinus or right atrium (RA) directly. Supracardiac forms have PV return to the superior vena cava (SVC) or innominate veins (often via a vertical or ascending venous connection from the confluence). Infracardiac forms include PV return to various inferior structures including the inferior vena cava, portal venous system or hepatic veins (often via a descending inferior vein which penetrates the diaphragm). Mixed-type TAPVR involves 2 or more of these variances. The latter of these is the most rare type, ranging typically from ~11%-12.3%[6,7] in various single-center studies, though as low as 3-4%[8,9] and as high as 20-21%[10,11]. TAPVR can also be separated based on cardiac defects. Simple (or isolated) TAPVR may include an additional atrial septal defect (ASD) or patent ductus arteriosus, while complex TAPVR includes at least one other complex cardiac defect[12].

Mixed-type TAPVR can be further classified based on pattern of PV drainage. Type I refers to '2+2' drainage of venous pairs, type II refers to '3+1', and type III refers to all other variants[13]. This classification may be significant as the risk of death is 5.8 times higher in type III in one study[14]. Mixed-type TAPVR in itself has a higher mortality, with univariate analysis of mixed type versus cardiac type (lowest mortality of TAPVR variants) demonstrating statistically significant hazard ratios of 2.88 in previous study[7], and mortality as high as 42-50%[15,16]. Other determinants of increased mortality or transplant in this study include complex TAPVC and postoperative length of stay, while older age, weight greater than 2.5 kg, non-emergent operation, lack of PV obstruction, cardiac and supracardiac types were associated with increased survival to discharge[7]. Additionally, prolonged cardiopulmonary bypass (CPB) time and infracardiac involvement have been correlated with increased risk of mortality[15].

Overall TAPVR mortality may be decreasing with time[7], which may be partially due to earlier recognition and a change in preoperative diagnostic strategies over

recent decades. Complex mixed-type TAPVR has now been demonstrated in fetal ultrasound as early as 18 weeks[17]. There has been a move towards more advanced post-natal imaging including the use of angiography. An earlier clinical study of TAPVR cases from 1983-1993 demonstrated confirmatory diagnosis (following 2D echocardiogram with color doppler) by catheterization or magnetic resonance imaging in only 17/36 patients, the other 19 diagnosed intraoperatively or by autopsy[18]. For reference, sensitivity and specificity of echocardiography for anatomic diagnosis in mixed type TAPVR may approach 31% and 100%, versus 94% and 99% in cardiac catheterization[19]. This is not without risk, however, and the value and importance of angiography in preoperative planning due to the complex variance of mixed-type TAPVR anatomy is increasingly recognized[20,14]. A recent study by Turkvatan et al.[12] demonstrated 100% diagnostic agreement between preoperative low-dose multidetector computerized tomography angiography (CTA) and intraoperative findings, including all 5 of their mixed-type patients (supracardiac and cardiac anomalies referenced). Similarly, Fulanetto et al.[10] reference CTA with 3D reconstruction assisting with improved outcomes (8% mortality in their mixed-type cohort which included 3 type III variants).

While TAPVR literature has continued to compound, there remains relatively limited mixed-type TAPVR-specific case series. The following is a retrospective clinical review. We aim to describe and display the anatomic variance and surgical technique used in the operative repair of one surgical group's experience with 14 mixed-type TAPVR patients between 2004-2018 in an attempt to add to the comprehensive available data with which clinicians can use to optimize decision-making in a rare congenital lesion bearing significant mortality.

Materials and Methods

The Institutional Review Board approved the data collection for this study (approval number: 2245682, date:18.12.2024) and the need for patient consent for enrollment and publication was waived because of the retrospective design. Literature review via PubMed search was performed with combinations of the following keywords: 'TAPVR', 'TAPVC, 'mixed type', and 'surgical technique'. Patient data was reviewed to outline objective data listed in tables IV-VII and artistic visualizations were provided to aid with interpretations and overall understanding of lesions. Illustrations were drawn by professional audio-visual expert.

Statistical Analysis

As our study is a retrospective, we used descriptive statistics for all the continuous variables were reported as mean ± standard deviation while categorical variables were reported as frequencies and percentages.

Surgical Technique

All patients received satisfactory endotracheal anesthesia and sterile prep. Visualization was made in all cases via a standard median sternotomy followed by opening of pericardium in midline and dissection for confirmation of TAPVR anatomy. Patients were heparinized, cannulated, and placed on complete blood profile (CBP). Aorta cross-clamped and cooling targeted mild hypothermia or deep hypothermia cardiac arrest depending on anticipated case difficulty. Dual caval snares were placed except if procedure required avoidance of PV distribution on SVC. Right atriotomy was typically made for cardiac subtypes. Ascending veins if present were either doubly ligated or ligated near confluence and reflected back to left atrium (LA), details which are further described in morphologies section. Autologous pericardium was used when needed for redirecting venous drainage, wall closure, or septation, with only two exceptions where bovine pericardium was used (patients L and N). Details of repair were overall dependent on variation in mixed type anatomy and outlined elsewhere in the morphology section. Suture type most frequently used included 5-0, 6-0, and 7-0 prolene or polyprolene, though also included PDS and Maxon variants. Venae cava snares were then released. Rewarming performed

with warm blood cardioplegia while venting through the aortic root. Pressure monitoring lines were inserted in few cases where hemodynamics deemed necessary. Weaned off CPB once normothermic, then decannulated once stable. Protamine given for heparin reversal then chest tubes and temporary pacer wires placed once hemostasis obtained. Sternum was either closed in layers or left open depending on complexity of repair. If left open, gap in skin was covered with an Esmarch patch and sewn to skin edges with 4-0 nylon. Wounds were cleaned and dressed appropriately. Instrument, sponge and needle counts were carried out twice.

Complications

There were few procedural complications. Patient F had bleeding due to incisions to upper and lower L PVs, felt likely made during dissection. This was corrected via autologous pericardium for upper vein and primary repair for lower vein. Two other procedures required extended duration due to findings at conclusion of their case, both of which had significant other cardiac comorbidities. Patient L had continued narrowing at SVC repair site which was subsequently augmented with a patch of bovine pericardium, however after weaning off CBP it was felt to still be unoptimized so required a 2nd pump run for additional bovine patch repair. Finally, patient H had tension at arch anastomosis site noted during rewarming, requiring deep hypothermia circulatory arrest and arch reconstruction. This was followed by TEE noting SVC obstruction at RA junction, for which SVC was re-implanted to right atrial appendage without CBP.

Morphologies

(Type I): 2+2

Six patients (43%) displayed type I morphology (Table 1). All of these included supracardiac connection, 4 had cardiac connection (pts A, B, F, G), 2 had infracardiac connection (pts D, M). One supracardiac connection was on the right (R pulmonary veins to SVC; pt F), otherwise all supracardiac connections involved L pulmonary veins draining to the innominate vein via a confluence and vertical vein. Cardiac connections varied, 2 of which included R PVs to coronary sinus (pts A, G), 1 with R PVs to SVC/RA junction (pt B), 1 with L PVs via confluence

Table 1.

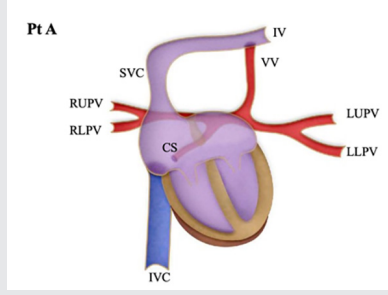
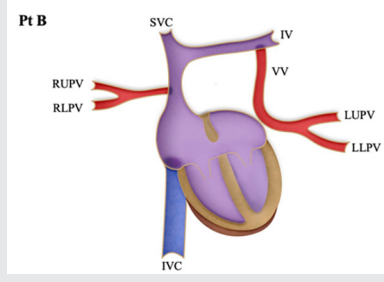
Patient ID	Anatomical variations	Illustration
Pt A	Type I: 2+2 Supracardiac connection + cardiac connection	
Pt B	Type I: 2+2 Supracardiac connection + cardiac connection	

Table 1. Continued

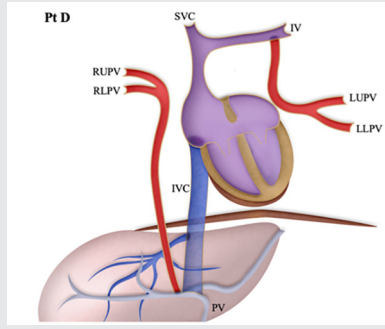
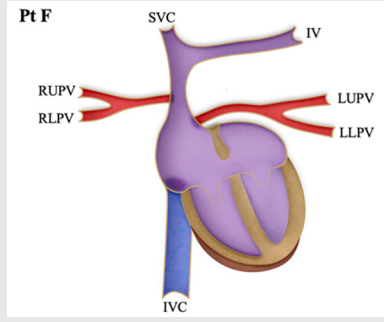
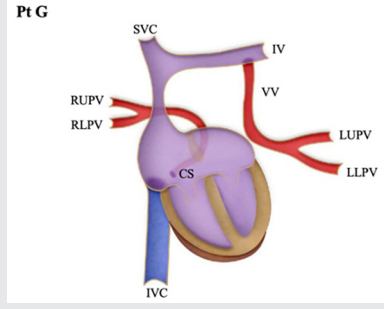
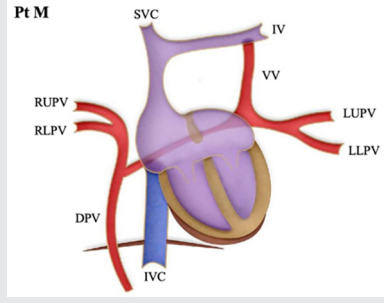
Patient ID	Anatomical variations	Illustration
Pt D	Type I: 2+2 Supracardiac connection + infracardiac connection	
Pt F	Type I: 2+2 Supracardiac connection + cardiac connection	
Pt G	Type I: 2+2 Supracardiac connection + cardiac connection	
Pt M	Type I: 2+2 Supracardiac connection + infracardiac connection	

Illustration of different anatomical variations of type I for patients A, B, D, F, G, and M. RUPV: Right upper pulmonary vein, RLPV: Right lower pulmonary vein, SVC: Superior vena cava, CS: Coronary sinus, IVC: Inferior vena cava, IV: Innominate vein, VV: Vertical vein, LUPV: Left upper pulmonary vein, LLPV: Left lower pulmonary vein, PV: Portal vein, DPV: Descending pulmonary vein

into RA (pt F). One of the coronary sinus variants had a connection between the R and L venous confluences, which was utilized during surgical technique (pt A). Infracardiac connections included a R descending vein connecting R PVs to portal vein (pt F), and one unusual connection with a R confluence which drained below the diaphragm towards the liver, as well as transversely to a L PV confluence (pt D).

Of the 5 L vertical veins, 4 were doubly-ligated and divided, while one was ligated and reflected for anastomosis of L PVs to LA (pt G). For the L PV confluence to RA, the confluence was close enough to the LA that mirrored incisions were made for direct anastomosis at that location (distal to confluence ligated and removed). For the two coronary sinus attachments, the sinus was unroofed for drainage into LA. Of these, the patient with a connection between their R and L confluences had their L vertical vein doubly ligated and removed, leaving all pulmonary veins to drain through the coronary sinus (confirmed unobstructed). The SVC-RA connection was directed to the LA via autologous pericardium. One of the infracardiac variants had the left and right confluences connected to each other after bilateral vertical vein ligation and detachment, following which both were attached together to the LA (pt D). The latter infracardiac variant mentioned (pt M) had each PV confluence attached to the LA separately (each via 6-0 PDS suture), otherwise similarly having ligation and division of other vertical veins as well as the inter-confluence connection.

(Type II): 3+1

Four patients (29%) displayed type II morphology (Table 2), all of which were cardiac/supracardiac variants (pts I, K, H) with the exception of a rare supracardiac/supracardiac combination (pt C). The left upper pulmonary vein (LUPV) emptied into the innominate via a vertical vein in all but one case (pt H) where it emptied with the L and R LPVs into the RA [in this pt the right upper pulmonary vein (RUPV) emptied into the SVC]. Two of the other PV trios drained into the coronary sinus (pts I, K), while one combination drained into the SVC (this being the supracardiac/supracardiac variant).

Table 2.

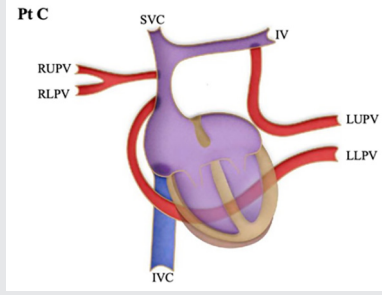
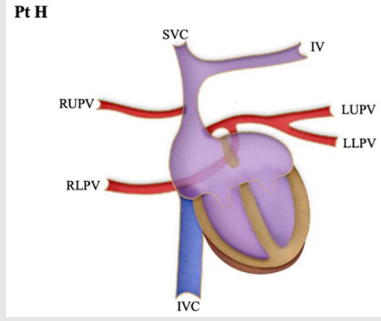
Patient ID	Anatomical variations	Illustration
Pt C	Type II: 3+1 supracardiac/supracardiac combination	
Pt H	Type II: 3+1 cardiac/supracardiac variants	

Table 2. Continued

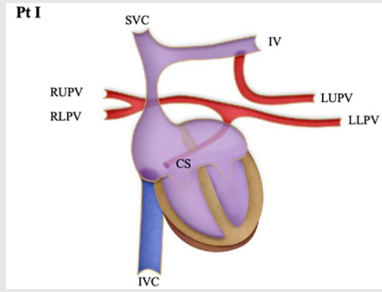
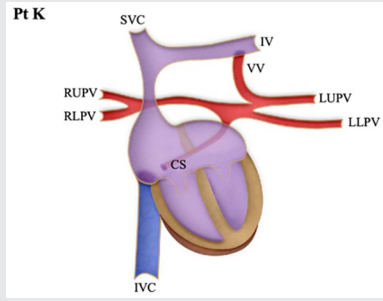
Patient ID	Anatomical variations	Illustration
Pt I	Type II: 3+1 cardiac/supracardiac variants	
Pt K	Type II: 3+1 cardiac/supracardiac variants	

Illustration of different anatomical variations of type II for patients D, I, J, L. RUPV: Right upper pulmonary vein, RLPV: Right lower pulmonary vein, SVC: Superior vena cava, CS: Coronary sinus, IVC: Inferior vena cava, IV: Innominate vein, VV: Vertical vein, LUPV: Left upper pulmonary vein, LLPV: Left lower pulmonary vein

Details regarding the repair of the supracardiac-supracardiac morphology were unavailable (pt 'C'). Vertical veins when present for LUPV to innominate connection were singly ligated and reflected back to the LA (including pt who had an additional but obstructed connection from LUPV to confluence). Coronary sinus was unroofed followed by autologous pericardial ASD closure in both cases with confluence drainage into sinus. In the patient with PV drainage to the SVC and RA, the atrial septum was fully excised to an existing sinus venosus ASD followed by autologous pericardial patch redirection of all PVs into the LA. As noted in the complication section above, this repair did result in SVC-RA obstruction ultimately requiring re-implantation of SVC to R atrial appendage (pt H).

(Type III):

Four patients (29%) displayed type III morphology (Table 3). Two of these patients had 3+2 anatomy with supracardiac and cardiac connection, both of which included 3 right-sided pulmonary veins (pts N,L). The first of these had 2 small RUPVs which emptied into the SVC, while the LPVs and the right lower pulmonary vein (RLPV) emptied directly into the RA (pt N). The second (pt L) - who also had tetralogy of fallot (TOF) - had LPVs drain via vertical V to a retroaortic innominate V, with more complex variance in the R sided veins (RLPV to LA, RMPV and RUPV to SVC). The remaining two patients had rather unique anatomy. One of these (pt E) had a mixed variant including a tri-level attachment: cardiac, supracardiac (which was inferred, as true drainage was unclear), and infracardiac connection. The RPVS attached to a multitude of locations, including the RA, a PV confluence, and a descending infra-diaphragmatic vein. The LVs attached more classically to PV confluence, though also with a vertical vein which was difficult to determine exact location of emptying. The last patient (J) had LPVs and RLPV all attached to the SVC-RA junction via a L confluence, while the RMPV directed into the RA and RUPV into the SVC (resemblance of a '3+1+1').

Surgical repair was dependent on lesion, however technique largely involved similar strategies to those used in types I and II. Decision was made not to intervene on the tiny RUPVs on the first of the above 3+2 variants (pt N), while the remaining RA attachments were re-routed to the LA by a bovine patch following ASD enlargement. The other 3+2 variant had a complete ligation of vertical vein and anastomosis to LA, while the SVC was opened for disconnection of the RUPV and RMPV, which were re-anastomosed to the LA. Autologous pericardium was

Table 3.

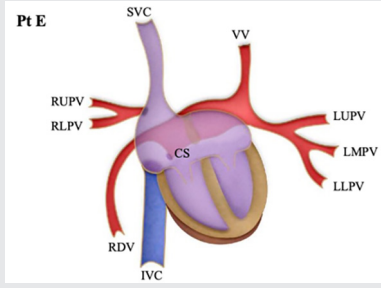
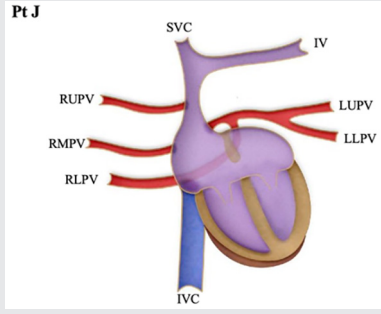
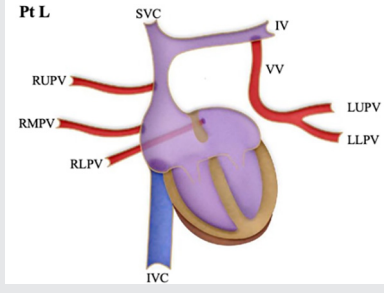
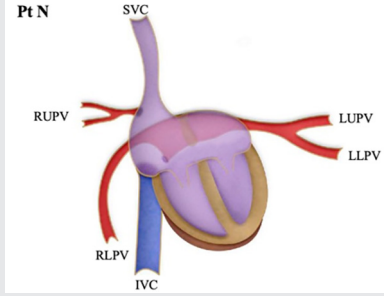
Patient ID	Anatomical variations	Illustration
Pt E	Type III: Mixed variant including a tri-level attachment: cardiac, supracardiac and infracardiac connection	
Pt J	Type III: LPVs and RLPV all attached to the SVC-RA junction via a L confluence, while the RMPV directed into the RA and RUPV into the SVC	
Pt L	Type III: 3+2 anatomy with supracardiac and cardiac connection	
Pt N	Type III: 3+2 anatomy with supracardiac and cardiac connection	

Illustration of different anatomical variations of type III for patients F, K, M, O. RUPV: Right upper pulmonary vein, RLPV: Right lower pulmonary vein, RDV: Right descending vein, RMPV: Right middle pulmonary vein, SVC: Superior vena cava, CS: Coronary sinus, IVC: Inferior vena cava, IV: Innominate vein, VV: Vertical vein, LUPV: Left upper pulmonary vein, LLPV: Left lower pulmonary vein, LMPV: left middle pulmonary vein

used to direct SVC flow to RA. This was all in addition to a complete TOF repair. Similarly, the '3+1+1' variant had their SVC extensively opened (to the innominate V) to accommodate a large autologous pericardium for redirection of the RUPV and RMPV to the LA. The confluence containing the LPVs and the RLPV was otherwise detached and anastomosed to the LA. The pt with tri-level attachment had classic incision and anastomosis of the L confluence to the LA. The remaining RA drainage was redirected into the same LA anastomosis via elongation of the atrial incision, followed by ASD closure.

Findings

Baseline demographic data is outlined in (Table 4). Of note, all patients were under 6 moths old except for two (10 moths, 132 moths), exaggerating the mean age and weight some. All three patients who died had weights greater than 4 kg at initial operation.

Pertinent preoperative data are outlined in (Table 5). Regarding mortality, 1/7 patients who underwent catheterization, 1 of the patients who received computerized tomography angiogram, and the patient who had 3-D printing performed ultimately died. Despite this, 3-D printing was deemed by the surgical team to be helpful in facilitating discussion regarding surgical approach. Patients with complex intracardiac lesions both died as well. Interestingly, none of the three patients who had obstruction indicated in operative note deceased, a number that would be discrepant from much of the literature. Pt 'N', whose course is outlined further below, developed obstruction later and did die. Even in these 4 patients, 25% obstruction mortality may still be low in relation to available data in some mixed type TAPVR

Table 4. Baseline data

	% Male (n)	% Female (n)	
Sex	50 (7)	50 (7)	
	Median	Mean	Range
Age (mo)	3.2	12.4	0.26-132
Weight (kg)	4.335	5.775	2.7-27.7
BSA (m2)	0.25	0.275	0.17- 0.7

Table depicting baseline demographic value for all 14 patients in series. mo: Month; kg: Kilogram; m2: Meters squared, BSA: Body surface area

Table 5. Preoperative data

Workup performed	% present (n)	Detail
Echocardiogram	100 (14)	
Cardiac catheterization	50 (7)	
CTA	14 (2)	Pts: K, N
Cardiac MRI	7 (1)	Pt: M
3-D print reconstruction	7 (1)	Pt N
Anatomic findings	% present (n)	Detail
Obstruction	21 (3)	Pts: B, C, D, N
Complex intracardiac lesions	14 (2)	Pt H = VSD Pt L = TOF
Non-complex intracardiac lesions	71 (10)	ASD in 10 of these, PDA in 9
Other anomalies	29 (4)	PHTN, b/l SVC, Ao arch hypoplasia, pleural-pericardial communication

Table depicting preoperative values for all 14 patients in series. CTA: Computed tomography angiogram, MRI: Magnetic resonance imaging, Pt: Patient, VSD: Ventricular septal defect, TOF: Tetralogy of fallot, ASD: Atrial septal defect, PDA: Patent ductus arteriosus, PHTN: Pulmonary hypertension, b/l: Bilateral, Ao: Aorta

cohorts, which can approach 100%[19]. As is discussed in limitations, the sample size of this series is not able to conclude any association with these findings.

Intraoperative data are presented in (Table 6). Circulatory arrest was reported in 6 patients, one of which was discarded (reported as 1-minute, unclear validity). Prime volume was also only occasionally reported. Temperature ranges for mild, moderate, and deep hypothermia were determined based on Saad citation [21], though others site different ranges. Both of the patients whose bypass times were greater than 4 hours ultimately died (cross-clamp times greater than 2.5 hours). There did not appear to be any recognizable patterns with temperature regulation, drainage, or monitoring devices.

Postoperative data is presented in (Table 7). There appeared to be no pattern regarding initial admission length, including pt 'J' whose stay was ~6 months and remains alive as of this report. It should be noted that pt 'N' had a rather extensive and complex course that included re-operation due to baffle dehiscence of original ASD, and 2 months later for PV obstruction from cor triatriatum membrane. Patient was also the only readmission (failure to thrive) which was complicated by pulmonary edema with profound respiratory failure felt to

Table 6. Intraoperative data

	Median	Mean	Range
CPBT	118 min	136 min	65- 270 min
XCT	69.5 min	85.7 min	36-176 min
Circulatory arrest Time (n=5)	43 min	38.8 min	20- 51 min
Prime volume (n=5)	650 mL	607 mL	500-700 mL
Temperature (n=13)	% present (n)	Detail	
Mild hypothermia	31 (4)	32°, 34°	
Moderate hypothermia	15 (2)	28°	
Deep hypothermia	54 (7)	16°, 18°	
Devices placed (n=13)	% present (n)	Detail	
Mediastinal CT	92 (12)		
Pericardial CT	46 (6)		
Pleural CT	85 (11)	One unilateral (Pt: I), all others b/l	
Peritoneal catheter	46 (6)		
LA pressure line	15 (2)	Both also had pulmonary artery pressure monitor	
RA pacer wires	100 (13)		
RV pacer wires	23 (3)		

Table depicting intraoperative values for available patient data. CPBT: Cardiopulmonary bypass time, XCT: Cross-clamp time, min: minute, mL: Milliliter, mild hypothermia: 32-35°C; moderate hypothermia: 26-31°C, deep hypothermia: < 26°C; CT: Chest tube, b/l: bilateral, LA: Left atrium, RA: Right atrium, RV: Right ventricle

Table 7. Postoperative data

	Median	Mean	Range
Initial hospital stay (n=13)	13 d	45.4 d	9-193 d
	% present (n)	Detail	
Mortality	21 (3)	Pts: C, L, N Time to death: 1 mo, 2 mo, 6 mo	
Post-op echo obstruction	29 (4)	1 spontaneous resolution on follow-up echo; 3 w/o obstruction mentioned pre-op	

Table depicting postoperative values for available patient data. d: Days; mo: Month, Echo: Echocardiogram

be contributed to by PV obstruction. Of note, this patient also had one anomalous PV which was not manipulated at initial repair, as mentioned above. Two-staged repairs have been successfully reported in the literature, though have involved avoidance of LUPV repair[22,23]. It is unclear whether this contributed at all to this patient's demise. Postoperative echocardiograms revealed obstruction in 4 patients who did not have it preoperatively, for unclear reasons other than in pt 'N'. Two of these patients ('N', 'H') are deceased. Anatomically, one of the deceased patients was type II ('H'), the others type III ('L', 'N'). There was no mortality in type I connections.

Discussion

This study outlines the complex variance in mixed type TAPVR patients, and to our knowledge only 5 other mixed type-specific retrospective case series [15,24,10,14,25] exist in the literature, though we acknowledge mixed type data can be found within generalized TAPVR studies. The intent of this data was to add to the literature for purposes of future meta and systematic analyses to improve surgical approach, as well as serve educational purposes regarding a rare and intricate lesion.

Interestingly, in this cohort there was no intraoperative mortality. This appears low in comparison to data in available studies, including a 768-patient cohort by Shi et al.[26] which included 38 intraoperative deaths (5%), though this article did not include mixed-type specific data. Other studies site operative mortality rates for mixed-type TAPVC of 19.3%[14] and up to 50%[16], though the latter included 2/5 deaths which included single ventricle anatomy as a comorbidity. Our cohort did not include any single ventricle anatomy, however one patient did have complex congenital disease (tetralogy of fallot) and ultimately did not survive. Additionally, both patients who had complex intracardiac lesions (per mixed type TAPVR classification) died (tetralogy of fallot, ventricular septal defect). This is one of three total mortalities (rate of 21%), all occurring within the first year. This rate is lower than that of a similar cohort, citing 42% in first year[15]. It is difficult to account for this difference, as our cohort included a higher percentage of both infradiaphragmatic connections as well as type 3 lesions, both of which are deemed to have higher mortality rates. This is also a lower rate than a larger TAPVR analysis, where mixed type mortality rate was 30%[7].

Aside from the complex intracardiac lesion finding related to mortality, the following were other pertinent observations regarding the available data as outlined above. Patients who died were all greater than 4 kg at operation (5 patients were under 4 kg). No patients with preoperative obstruction at initial surgery died. 3-D print reconstruction was performed in 1 patient and deemed helpful for initial repair, though ultimately patient did die. Both patients with bypass times greater than 4 hours (cross-clamp times greater than 2.5 hours) died. The other, as previously mentioned, had a short bypass time, but prolonged and complex course including two additional operations (baffle dehiscence, cor triatriatum repair).

Study Limitations

There were notable limitations in this study. Given that this was an observational retrospective cohort, there is no correlational data. The majority of our data collected (aside from outcomes) from our cohort is from operative notes, relying on accuracy of the note writer and consistency of full completion. Certain data was also unavailable to be retrieved when analysis performed, specifically patient C who's operative note was not located. Also, one of the patients operated on was at a center in a different country than the previous 13 (patient N), lending potential for institutional differences to contribute to outcome data. Lastly, given small sample size the results are difficult to make meaningful inferences from, however this is consistent with previous cohorts given the rarity of this disease, and contribution to a future systematic review may prove effective.

Conclusion

Mixed type TAPVR presents a wide variety of connections, lending to the complexity in planning and

execution of surgical correction. Our study contributes further to the available data on this more rare form of TAPVR, which may be important as more cohorts emerge with varying success rates. More widespread studies, including systematic review may be beneficial to further characterize morphology, intraoperative technique, outcome data, and perhaps most importantly, specific indices for predicting higher survival or mortality rates.

Ethics

Ethics Committee Approval: The Institutional Review Board approved the data collection for this study (approval number: 2245682, date:18.12.2024).

Informed Consent: The need for patient consent for enrollment and publication was waived because of the retrospective design.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Dawary M, Khouqeer F, Issa Z, Alkhalaf L, Alshamdin F, Griselli M, Concept: Dawary M, Khouqeer F, Issa Z, Griselli M, Design: Dawary M, Khouqeer F, Griselli M, Data Collection and/or Processing: Dawary M, Issa Z, Alkhalaf L, Alshamdin F, Griselli M, Analysis and/or Interpretation: Dawary M, Khouqeer F, Issa Z, Alkhalaf L, Alshamdin F, Griselli M, Writing: Dawary M, Khouqeer F, Griselli M.

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Research Article

155

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Effect of Regional Versus Local Anesthesia on Outcomes of Radiocephalic Arteriovenous Fistula Creation for Hemodialysis Access: A Prospective Randomized Study

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Abstract

Objectives: To investigate the effect of regional versus local anesthesia on perioperative outcomes in patients with end-stage renal disease undergoing radiocephalic arteriovenous fistula for hemodialysis access.

Materials and Methods: A total of 80 patients who underwent primary radiocephalic arteriovenous fistula were included in this study and randomly and equally divided into two groups; as regional anesthesia group (n=40) and local anesthesia group (n=40). The basic clinical characteristics and perioperative outcomes of the patients were recorded and compared between the groups.

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Abstract

Results: The mean ages were 59.7 years in the regional anesthesia group and 60.4 years in the local anesthesia group. Twenty-nine (72.5%) of the patients in the regional anesthesia group and 26 (65%) of the patients in the local anesthesia group were male. The groups were statistically similar in terms of basic clinical characteristics. There were no significant differences in postoperative complications, including bleeding and wound infection, between the groups. There were no significant differences in immediate, primary, and functional patency rates between the groups, and both groups were statistically similar.

Conclusion: Compared with local anesthesia, regional anesthesia has not significant impact on perioperative outcomes in patients with radiocephalic arteriovenous fistula for hemodialysis access.

Keywords: Regional anesthesia, local anesthesia, radiocephalic arteriovenous fistula

Introduction

Hemodialysis is the most commonly used renal replacement therapy for patients with end-stage renal disease (ESRD). An autogenous arteriovenous fistula (AVF) is the most appropriate option for hemodialysis access because of their association with lower thrombosis and infection risks, increased quality of life, and longer life expectancy[1]. On the other hand, in some patients with autogenous AVF, AVFs cannot be used for hemodialysis access for various reasons. In the literature, the rate of patients who cannot access hemodialysis through autogenous AVFs is between 10% and 50%[2]. AVF failure is frequently observed in patients who undergo radiocephalic AVF creation on small diameters and distal vessels at the wrist level. Several factors such as small cephalic vein and radial artery diameters, insufficient blood flow in the radial artery, and obstruction or occlusion in the cephalic vein increase the risk of radiocephalic AVF failure[3].

AVF can be created using various anesthesia techniques, including local anesthesia (LA), regional anesthesia (RA), such as brachial plexus block (BPB), and general anesthesia. In patients with ESRD, local and RA methods are almost always preferred over general anesthesia for creating AVF because of general anesthesia-related adverse events and frequent comorbidities[4]. There is no exact evidence that any one anesthetic approach could have a substantial impact on AVF outcome or failure even if RA procedures could directly influence vessel diameters and perioperative blood flow. In other words, it is still controversial whether RA is exactly superior to LA in terms of postoperative outcomes in patients created AVF. Thus, we designed this study to examine whether BPB and LA, the two most commonly used anesthesia methods for AVF creation, make a significant difference in postoperative outcomes in patients undergoing radiocephalic AVFs[5,6]. Thus, we designed this study to examine whether BPB and LA, the two most commonly used anesthesia methods for AVF creation, significantly affect postoperative outcomes in patients undergoing radiocephalic AVF.

Materials and Methods

Ethics Committee approval was obtained from the Uludağ University Faculty of Medicine Clinical Researches Ethics Committee (approval no.: 2017-10/31 date: 04.07.2017), and the study was conducted based on the ethical rules of the Declaration of Helsinki. The patients included in the study were informed about not only the operation but also the study, and written informed consent was obtained.

Patients and Study Design

This prospective randomized comparative study included patients undergoing autogenous radiocephalic AVF for hemodialysis access. A total of 80 patients were randomly assigned using a computer-generated allocation system to receive either regional or LA and equally divided into two groups. During the operation, patients in group 1 were operated under RA while those in group 2 were operated under LA. The inclusion criteria were first-time primary native radiocephalic AVF operation at the wrist level. The exclusion criteria were age under 18 years, pregnancy, previous AVF operation, operations performed at levels other than the wrist level, and AVF operation using a synthetic graft. A CONSORT flow diagram for patients screened and excluded from the study is shown in Figure 1.

The patients' baseline clinical characteristics and perioperative outcomes were recorded and compared between the groups. All patients underwent routine Doppler ultrasonographic evaluation not only preoperatively but also in all postoperative control examinations. Doppler ultrasonographic evaluations were performed by a single experienced radiologist. In this study, the primary endpoint was primary patency at 3 months, while the secondary endpoints were immediate patency and functional patency at 3 months, as well as postoperative complications, including bleeding and wound infection. Immediate patency was defined as the existence of a thrill or bruit on the created AVF upon hospital discharge. Primary patency at 3 months was defined as the existence of a thrill or bruit on the created AVF in the absence of any additional intervention within the first 3 months after the operation. Functional

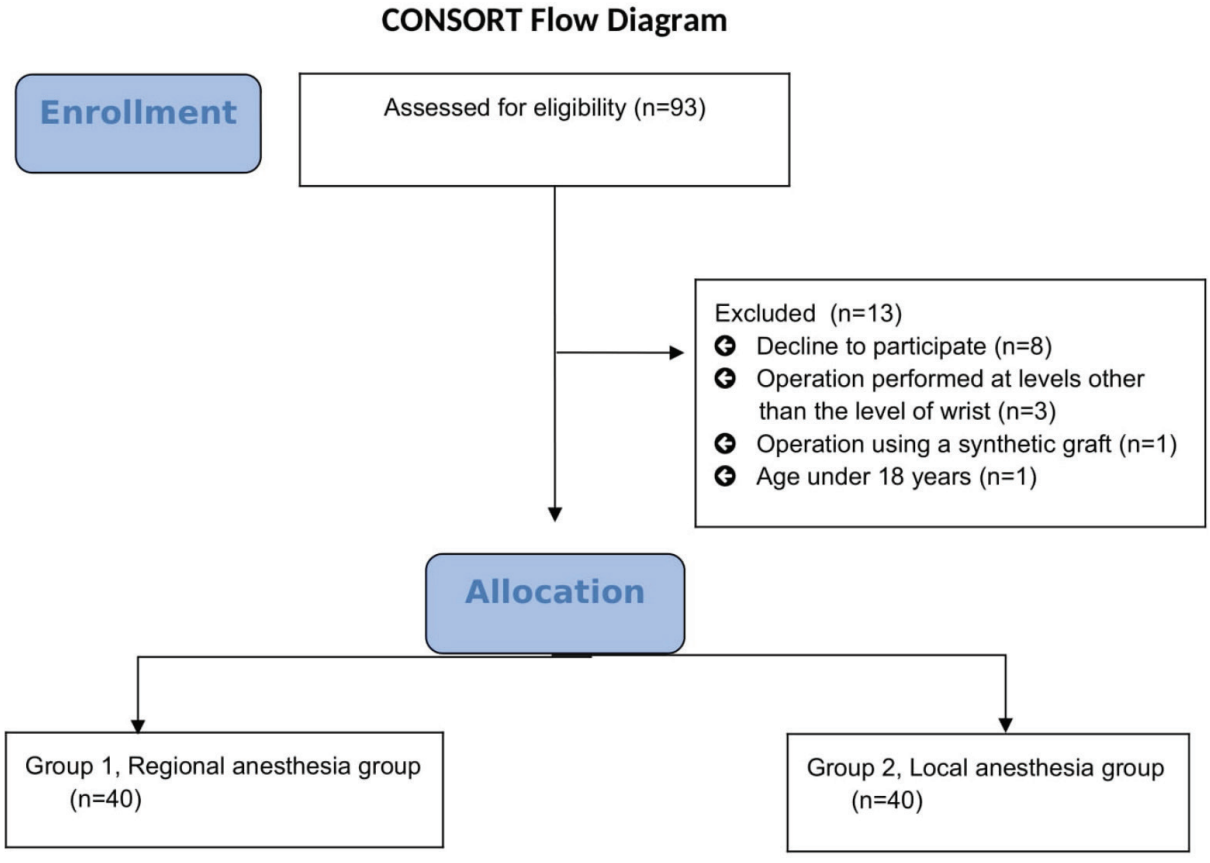

Figure 1. CONSORT Flow Diagram

patency at 3 months was evaluated both clinically (used in hemodialysis patients, or deemed suitable for vascular access by the expert hemodialysis nurse in predialysis patients) and ultrasonographically (> 5 mm diameter and flow rate > 500 mL/min).

Anesthesia and Operative Techniques

BPB was performed by expert anesthesiologists using an axillary approach. The patients were placed in the supine position with their arms abducted, and the axillary region was made aseptic. The nerves were identified using a needle-connected nerve stimulator system. When negative pressure was applied and no blood was seen, 5 mL of bupivacaine was applied at once. LA was provided with 10-15 mL of prilocaine subcutaneously after asepsis of the surgical field was achieved. All patients were operated on by the same surgical team. After preparing the radial artery and cephalic vein, 0.5 mL of heparin was intravenously administered to the patients. The cephalic vein was thoroughly freed to increase fistula flow. Anastomoses were performed using 7/0 polypropylene with the end-to-side anastomosis technique. After the completion of the anastomosis, the existence of a thrill or bruit was considered to indicate that the anastomosis was working. After surgery, low-molecular-weight heparin was administered for one week to prevent AVF thrombosis if not contraindicated.

Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences version 20.0 (SPSS Inc., Chicago, Illinois, USA). The conformity of continuous variables to normal distribution was investigated with Kolmogorov-Smirnov test. When comparing continuous variables with normal distribution, Student's t-test was used. The chi-square test was used to compare categorical variables. Data are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables. A p-value of less than 0.05 was considered statistically significant.

Results

The mean ages of the regional and LA groups were 59.7 and 60.4 years, respectively. Twenty-nine (72.5%) patients in the RA group and 26 (65%) patients in the LA group were male. The most common comorbid diseases in our study population were hypertension, coronary artery disease, and diabetes mellitus. The mean preoperative cephalic vein diameters at the level of wrist were 2.31 mm in RA group and 2.35 mm in LA group. There were no significant differences between the groups in terms of the analyzed baseline clinical characteristics, and the groups were statistically similar (Table 1).

Table 1. Baseline clinical characteristics

Variable	Group 1 (Regional anesthesia)	Group 2 (Local anesthesia)	p-value
Age (year)	59.7±11.2	60.4±11.0	0.764
Gender (male)	29 (72.5%)	26 (65%)	0.469
Obesity (BMI >30 kg/m²)	12 (30%)	11 (27.5%)	0.805
HT	28 (70%)	30 (75%)	0.617
DM	12 (30%)	13 (32.5%)	0.809
CAD	15 (37.5%)	16 (40%)	0.818
Cephalic vein (wrist) diameter (mm)	2.31±0.20	2.25±0.18	0.157
Radial artery diameter (mm)	2.13±0.08	2.11±0.09	0.369

BMI: Body mass index, HT: Hypertension, DM: Diabetes mellitus, CAD: Coronary artery diseas

Following the operations, thrill could not be received in two of the RA patients and five of the LA patients, and this difference was not statistically significant. Bleeding (>25 mL) was observed in two patients in the RA group, and these patients were re-explored for bleeding control on the same day after the operation. None of the patients in the LA group underwent re-exploration for bleeding. During the entire follow-up period, superficial wound infection was observed in one RA patient and two LA patients, and the infection regressed with oral antibiotherapy. The primary and functional patency status of the created AVFs were evaluated at 3 months after surgery. The primary patency rate was 87.5% for the RA group and 77.5% for the LA group, whereas the functional patency rate was 82.5% for the RA group and 70% for the LA group, and these differences were not statistically significant (Table 2).

Discussion

In this study, we compared the effects of local and RA on postoperative outcomes in patients undergoing primary radiocephalic AVF creation. The groups were similar in terms of age, sex, comorbidities, and preoperative vascular diameter, ensuring a balanced baseline for analysis. Our findings revealed no statistically significant difference in primary or functional patency rates between the two groups, although RA was associated with slightly higher rates. However, patients in RA groups experienced more bleeding complications, requiring re-exploration in some cases. These results were interpreted in light of the existing literature.

In most patients with ESRD who require hemodialysis, general anesthesia is not often preferred for AVF creation due to the presence of comorbid diseases, such as hypertension, diabetes mellitus, and coronary artery disease, as well as the risks for general anesthesia-related adverse events; rather, LA or RA methods, such as BPB, come to the fore for this purpose[4]. The sympathetic effects of RA, which enhance vascular diameter and improve intraoperative blood flow, have been extensively documented in previous studies[5-7]. For instance, Aitken et al.[5] demonstrated that RA led to better short-term patency rates than LA, although this advantage diminished in the long term. Additionally, RA facilitates distal anastomosis by increasing intraoperative venous diameters, potentially improving surgical outcomes[8]. In our study, the higher primary patency rates observed in the RA group, although not statistically significant, might reflect these effects. However, the lack of significance can be attributed to the limited sample size.

On the other hand, LA is associated with higher rates of vascular spasm, which may increase the risk of early thrombosis and AVF failure[9]. Despite these concerns, our findings suggest comparable blood flow and patency rates between local and RA, which is consistent with prior studies.

From a safety perspective, RA is an operator-dependent technique, and its success and complication rates are significantly influenced by the practitioner's expertise[10,11]. Despite its advantages, RA carries a risk of neurological complications if not administered accurately. Issues such as postoperative paresthesia or paralysis can arise from factors like intraneural injection, direct nerve trauma, ischemia caused by edema or hematoma formation, or neurotoxicity of the anesthetic

Table 2. Postoperative outcomes

Variable	Group 1 (Regional anesthesia)	Group 2 (Local anesthesia)	p-value
Bleeding (> 25 mL)	2 (5%)	0 (0%)	0.152
Wound infection	1 (2.5%)	2 (5%)	0.556
Immediate patency	38 (95%)	35 (87.5%)	0.235
Primary patency at 3 months	35 (87.5%)	31 (77.5%)	0.239
Functional patency at 3 months	33 (82.5%)	28 (70%)	0.189

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agent[12]. The higher re-exploration rates reported in the RA group suggest that the increased blood flow and vascular dilatation effects of RA may increase the risk of bleeding complications, especially in complex patients. Nonetheless, the similar infection rates between the groups in our study reinforce the overall safety of both anesthesia techniques.

Our findings suggest that LA is a feasible and effective option for creating an AVF in patients undergoing primary radiocephalic AVF, offering results comparable to those of RA without increasing the risk of bleeding or neurological complications. Although RA confers potential advantages in vascular hemodynamics, these benefits must be weighed against their complication profile, particularly in centers with limited operator expertise. These results are consistent with the existing literature and highlight the need for individualized anesthetic strategies based on patient characteristics and surgical requirements. Future studies with larger patient cohorts and extended follow-up periods are warranted to further validate these findings and optimize anesthesia practices in AVF surgery.

Study Limitations

This study has several limitations that should be acknowledged. First, the relatively small sample size may have limited the statistical power to detect significant differences in primary and functional patency rates between the groups. Second, our follow-up period was limited to 3 months, which may not capture long-term outcomes such as sustained patency and successful dialysis. Third, as a single-center study, the findings may not be generalizable to other institutions with differing patient populations, surgical techniques, or operator expertise. Lastly, the potential variability in RA administration, influenced by operator skill and technique, might have introduced biases. Future multicenter studies with larger cohorts and extended follow-up periods are needed to address these limitations and provide more robust evidence.

Conclusions

This study highlights that LA a is an effective and reliable option for primary AVF creation, yielding outcomes comparable to those achieved with RA. Although RA demonstrated a slight advantage in primary and functional patency rates, this did not reach statistical significance and was accompanied by higher bleeding-related complications requiring re-exploration. These findings suggest that although RA offers potential hemodynamic benefits, its risks and dependency on operator expertise warrant careful consideration. Tailored anesthetic strategies that prioritize patient safety and surgical efficiency should guide clinical decision-making. Further large-scale, randomized studies with long-term follow-up are necessary to confirm these results and provide more definitive recommendations.

Ethics

Ethics Committee Approval: Ethics Committee approval was obtained from the Uludağ University Faculty of Medicine Clinical Researches Ethics Committee (approval no.: 2017-10/31 date: 04.07.2017), and the study was conducted based on the ethical rules of the Declaration of Helsinki.

Informed Consent: Informed consent was obtained from all patients.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Atasoy MS, Güven H, Yüksel A, Müdüroğlu A, Çetintaş D, Kaya M, İşleyen M., Concept: Atasoy MS, Güven H, Yüksel A, Müdüroğlu A, Çetintaş D, Kılıç AÖ, Badem S, Çayır MÇ, Velioğlu Y, Design: Atasoy MS, Güven H, Yüksel A, Müdüroğlu A, Çetintaş D, Kılıç AÖ, Badem S, Çayır MÇ, Velioğlu Y., Data Collection and/or Processing: Atasoy MS, Güven H, Yüksel A, Kaya M, İşleyen M, Analysis and/or Interpretation: Atasoy MS, Güven H, Yüksel A,

Müdüroğlu A, Aldemir M, Velioğlu Y, Literature Search: Atasoy MS, Güven H, Yüksel A, Müdüroğlu A, Aldemir M, Writing: Atasoy MS, Güven H, Yüksel A.

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Successful Surgical Management of A Rare Popliteal Arteriovenous Fistula: A Case Report

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Abstract

Arteriovenous fistulas (AVFs) in the popliteal region present unique challenges in diagnosis and management because of their potential to cause significant complications. Surgical intervention, although uncommon, remains crucial in managing complex popliteal AVFs to preserve limb health and ensure optimal patient outcomes. This case underscores the importance of recognizing clinical evidence and employing diagnostic imaging to guide treatment decisions in lower extremity AVFs.

Keywords: Aneurysm, popliteal arteriovenous fistula, lower extremity vascular anomaly, vascular aneurysm

Introduction

Arteriovenous fistulas (AVFs) can occur in various locations throughout the body and may result from a range of causes, including congenital malformations, trauma, surgical procedures, or inflammation[1].

A specific type of AVFs that occurs in the popliteal region, known as a popliteal AVF, often poses clinical concerns due to its potential to cause complications, including vascular steal phenomenon, venous hypertension, and increased risk of thrombosis. The diagnosis and management of popliteal AVFs require a comprehensive understanding of the vascular anatomy, imaging techniques, and interventional procedures.

Treatment options for popliteal AVFs include conservative approaches, pharmacotherapy, and interventional procedures. Such as embolization and surgical correction[2].

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Case Presentation

A 58-year-old male presented with progressive swelling of the right leg and wounds in the foot with a history of knee operation and septic arthritis that required diagnostic functions. Lower limb digital subtracted angiography revealed a large popliteal AVF (Figure 1, 2). AVF is treated surgically at our center. AVFs of this size and morphology are rare. This case demonstrates a successful surgical method.

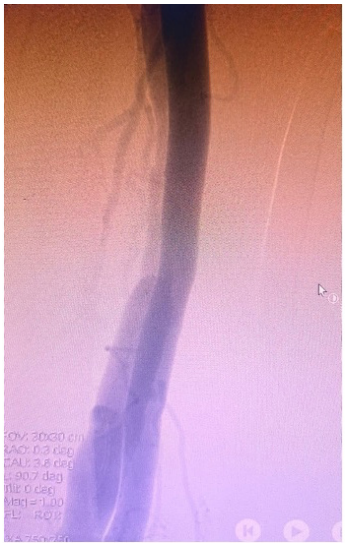

Figure 1. DSA image of the popliteal artery, popliteal vein and femoral vein-1
DSA: Digital subtraction angiography

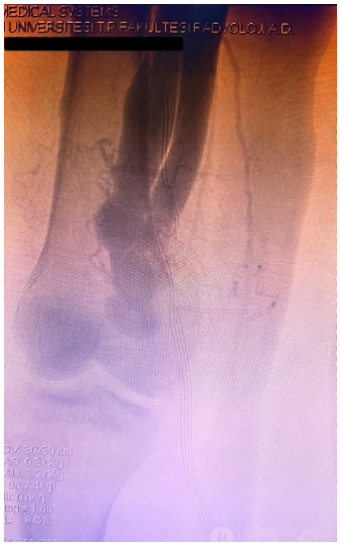

Figure 2. DSA image of popliteal artery and popliteal vein-2
DSA: Digital subtraction angiography

Our physical examination revealed edema around the right knee and thigh, with bruises. A strong thrill was detected in the medial and superior knee regions. The dorsalis pedis and tibialis posterior pulses were absent with palpation on the same side. Diagnostic Doppler USG was performed and showed monophasic flow in the crural arteries and a high-flow AVF between the popliteal vein and artery. Subsequent DSA revealed a prominent AVF with a width of 4 cm on a 5 cm segment in the popliteal region.

Surgery is planned. Because of the circumferential difference between the proximal and distal superficial femoral arteries, a treatment procedure with a covered stent was not possible. A 15 cm incision just superior to the knee was performed, and the popliteal vein and artery were exposed (Figure 3).

Tapes looped around the proximal and distal popliteal artery and vein. With vascular clamps following the injection of 1 cc fractioned heparin, the AVF connection is cut and both the popliteal vein and artery defects are repaired with over and over sutures (Figure 4, 5). A strong pulse was detected in the popliteal artery distal to the

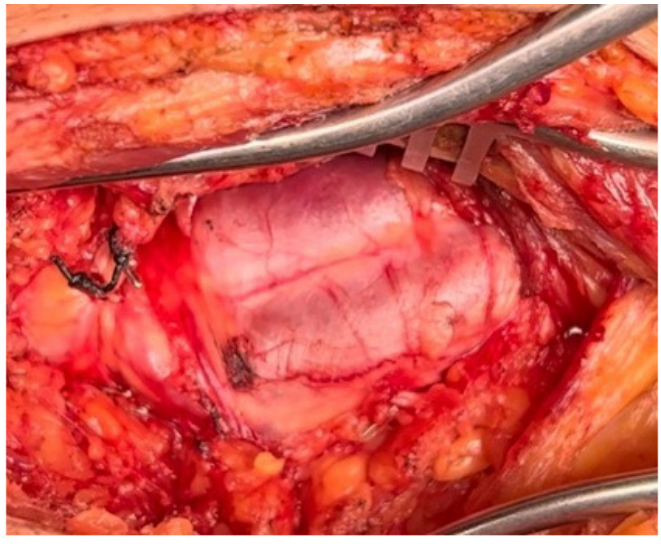

Figure 3. An intraoperative view showing the popliteal artery and popliteal vein

fistula connection. Informed consent was obtained from the patients prior to the procedure.

The patient is then extubated, and full subcutaneous anticoagulation plus compression socks treatment is recommended. The patient was externated within 2 days of follow-up, with no to minimal symptoms.

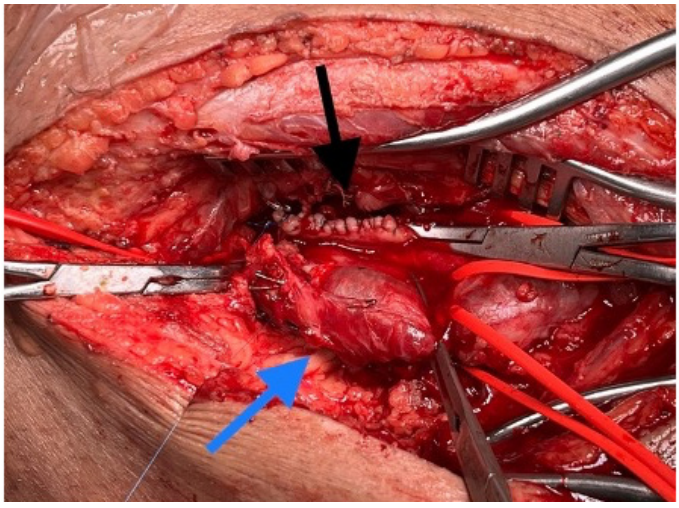

Figure 4. An intraoperative view showing AVF repairing
Blue arrow indicates popliteal artery
Black arrow indicates popliteal vein
AVF: Arteriovenous fistula

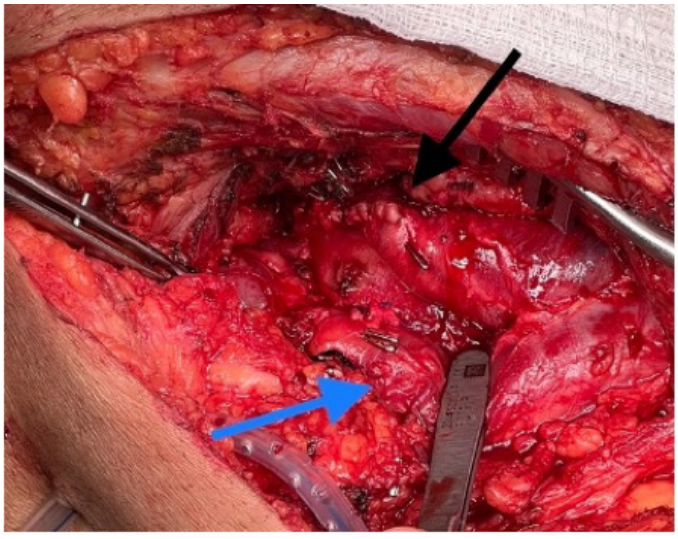

Figure 5. An intraoperative view showing AVF repairing
Blue arrow indicates popliteal artery
Black arrow indicates popliteal vein
AVF: Arteriovenous fistula

Discussion

This case report on a rare popliteal AVF emphasizes the importance of precise imaging, particularly digitally subtracted angiography, in directing the surgical approach. This patient had a considerably large AVF and our hospital lacked the experience of endovascular treatment (like embolization) experience of fistulas this size hence we have opted for surgery, specifically designed to the patient's unique vascular structure, due to the significant size and complexity of the AVF. Along with many surgical techniques like ligation (ligating the "neck" of the AVF, was not appropriate because of the size of the neck), resection, and end-to-end anastomosis-interposition with grafts (complete resection of the affected vascular structures and if possible anostomosing the remaining vascular ends if not possible using a greft be it vein or synthetic, for "interpositioning" the absent segment, whis is not our first choice), we preferred clamping the vein and artery distally and proximally with proper anticoagulation and directly cutting the wide "neck", ending the pathological flow then repairing the defects on both artery and vein side with sutures. If the defects were too large to be repaired or after closing the defects, there was a sign of stenosis like presence of the thrill of the turbulent flow, we would have performed complete resection and anostomosis interposition or vein patchplasty for the optimal results. The successful outcome of surgical treatment led to alleviation of symptoms, demonstrating the value of customized surgical planning and teamwork across specialties in managing complicated vascular conditions.

This case highlights the critical need for careful monitoring in patients with a history of multiple surgeries.

Conclusion

Iatrogenic and traumatic incidents are common causes of AVFs in the lower extremities, and they are often treated with conservative or minimally invasive methods. The presence of excitement and specific clues in patients' history should alarm the physician. DSA is a reliable

tool for diagnosis and treatment planning. In this case, the patient required open surgery, and the reason for the surgical intervention was mentioned. Treatment of lower extremity AVFs is extremely important for limb health, and a personalized treatment method should be discussed thoroughly for every patient's sake[3].

Ethics

Informed Consent: Informed consent was obtained from the patients prior to the procedure.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Demirtaş H, Yiğit D, Doğan A, Özer A, Concept: Demirtaş H, Yiğit D, Doğan A, Özer A, Design: Demirtaş H, Yiğit D, Doğan A, Özer A, Data Collection and/or Processing: Demirtaş H, Yiğit D, Doğan A, Özer A, Analysis and/or Interpretation: Demirtaş H, Yiğit D, Doğan A, Özer A, Literature Search: Demirtaş H, Yiğit D, Doğan A, Özer A, Writing: Demirtaş H, Yiğit D, Doğan A, Özer A.

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