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Comparison of Procedural Techniques and Variables in Patients Undergoing Arterial Cannulation

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ABSTRACT

Background: This study presents a comprehensive comparative analysis of two methods for arterial cannulation, palpation, and ultrasound guidance (USG), using a sample of 104 subjects for each method.
Methods: The primary objective was to evaluate the safety and efficiency of these techniques. Clinical and laboratory parameters were recorded, including hemoglobin levels, platelet count, International Normalized Ratio (INR), albumin, and total protein levels. The number of attempts and total procedure time were documented for each procedure. Additionally, the ultrasound-guided (USG) method and the duration of each recorded procedure were emphasized to provide a detailed comparison between the two techniques.
Results: USG required fewer attempts than palpation (1.63 ± 0.83 vs. 2.36 ± 1.18, p<0.001), resulting in a higher success rate on the first attempt. The total procedure time was significantly shorter in the USG group (7.14 ± 2.42 vs. 11.83 ± 4.45 minutes, p<0.001). This demonstrates the enhanced efficiency of USG. Complication rates were also lower in the USG group (16.3% vs. 31.7%, p=0.009), confirming its safety advantage.
Although the two groups showed no significant differences in hemoglobin levels, platelet count, albumin, total protein levels, inotropic agent requirements, or history of peripheral arterial disease (PAD) and congestive heart failure (CHF), INR levels were significantly higher in the USG group (1.23 ± 0.26 vs. 1.14 ± 0.25, p=0.004). Furthermore, patients with higher BMI benefited more from USG, which was particularly advantageous in challenging cases.
Conclusion: The current study demonstrates that USG is more efficient, safer, and quicker than palpation, particularly in patients with a higher BMI. These findings suggest that USG is preferable for arterial cannulation in clinical settings, offering reduced complications and enhanced success rates, especially in more challenging patient populations.

Keywords: Arterial cannulation, dorsalis pedis artery, palpation technique, USG technique

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Intraarterial cannulation is frequently used in intensive care units (ICU) for invasive blood pressure monitoring, frequent arterial blood gas analysis, and evaluation of fluid response in treatment.[1] Arterial cannulation plays a vital role in adequate hemodynamic monitoring.

Radial, dorsalis pedis, brachial, femoral, and posterior tibial arteries should be preferred for arterial cannulation.[1] Radial and dorsalis pedis arteries are chosen more frequently because of their proximity to the skin surface and ease of access.[2]

The traditional arterial cannulation method performs the procedure by palpating the planned vessel. An experienced physician is required for this procedure. Since multiple arterial interventions may be performed, arterial spasms and hematomas may occur.[3] With the complications in these procedures over time, ultrasound (USG) technique has become preferred. Its use in ICUs has grown due to fewer complications. Additionally, it requires less bedside time and offers higher success rates.[4,5]

Since the surgical outcomes related to the dorsalis pedis artery are not yet well understood, our study specifically selected it as the target artery for cannulation to contribute to the existing literature. Our research mainly aims to compare palpation and ultrasound guidance in vascular cannulations in the dorsalis pedis artery. The secondary objective was to find the total time, number of trials, complications, and success rates between the two procedures.

METHODS

This study compares 208 patients with arterial cannulation (104 for palpation and 104 for ultrasound techniques) and compares those patients undergoing arterial cannulation. After the local ethical committee's approval (Number: 2023-18/10), the study was conducted on patients in the internal medicine intensive care unit at a university hospital.

Criteria for inclusion:

- 18 years of age or older (including 18)
- Non-pregnancy

Exclusion criteria:

- Patients under 18 years old
- Pregnant patients
- Patients without approval
- Patients with diabetes, arterial thrombosis, infections, and related conditions were excluded

Patient selection and randomization:

Patients were randomly assigned to either the palpation or ultrasound-guided (USG) groups to minimize selection bias and ensure a balanced comparison between the two techniques.

Artery selection:

As stated in the introduction, the dorsalis pedis artery was selected for all procedures to maintain consistency across the study. Additionally, collateral circulation via the dorsalis pedis artery was assessed before cannulation.

Observer's role:

The observer documented key procedural parameters, including the number of attempts, total procedure time, and outcomes such as the success or failure of the intervention.

Switching to a different artery:

If cannulation of the dorsalis pedis artery was unsuccessful after multiple attempts, the physician proceeded to another artery based on clinical judgment to ensure patient safety and timely intervention.

In the study, an experienced internal medicine physician observed patients undergoing arterial cannulation. During the data collection process, no intervention was carried out concerning patient selection, indication of catheter installation, and vessel selection, and it was monitored only by an external observer. The data from patients who met the inclusion criteria were collected. Electronic medical records were used for the patient's laboratory parameters.

Our study used a 20G arterial cannula for palpation and ultrasound-guided cannulation. A vascular transducer with a small footprint (8–13 MHz) and a two-dimensional M-Turbo ultrasound system (Chison ultrasound) device were used for the procedure. The ultrasound was performed using a short-axis, in-plane technique. Both methods retained predefined times, which were not included in the total time. To objectively compare the total operating times, arterial palpation and detection times were included in the entire duration. Complications such as bleeding and hematoma were recorded after the catheter installation.

Statistical Analysis

All statistical analyses were performed using SPSS software (version 26 for Mac). The normality of the distribution of continuous variables was assessed using the Kolmogorov-Smirnov test. Data are presented as mean ± standard deviation (SD) for normally distributed variables and as median (min-max) for non-normally distributed variables.

Table 1. The comparison of continuous variables between the palpation and the USG technique used for arterial cannulation.

	Palpation (n=104)		USG (n=104)		p
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)	
Age	65.85 ± 14.94	67(24-96)	66.69 ± 16.13	68(18-93)	0.511
Height, cm	164.43 ± 9.6	162.5(145-184)	167.4 ± 9.47	170(150-185)	0.033
Weight, kg	85.79 ± 10.61	85(56-108)	84.43 ± 12.64	84.5(52-108)	0.580
BMI, kg/m²	31.86 ± 4.26	31.63(22.72-44.3)	30.18 ± 4.43	29.65(17.78-41.67)	**0.004**
Number of attempts	2.36 ± 1.18	2(1-5)	1.63 ± 0.83	1(1-4)	**<0.001**
Processing time, min	11.83 ± 4.45	11(5-23)	7.14 ± 2.42	6(4-13)	**<0.001**
MAP, mmHg	73.43 ± 11.58	71.67(48.33-105)	75.8 ± 27.04	71.67(48.33-321.67)	0.959
Systolic BP, mmHg	99.63 ± 15.49	95(65-145)	108.94 ± 75.48	100(75-855)	0.312
Diastolic BP, mmHg	60.34 ± 10.43	60(40-85)	59.23 ± 10.61	60(35-85)	0.397
Hemoglobin, g/dL	9.2 ± 1.14	9(7.3-12.5)	9.16 ± 1.5	8.9(6-13.2)	0.459
Platelet (10^3 µl)	154.89 ± 83.96	131.5(45-375)	156.68 ± 108.04	125(11-422)	0.577
INR	1.14 ± 0.25	1(0.8-2)	1.23 ± 0.26	1.2(0.9-1.9)	**0.004**
Albumin g/L	24.36 ± 3.58	24(18-32)	24.63 ± 5.36	24(17-38)	0.895
Total protein g/L	52.57 ± 7.31	55(35-67)	52.72 ± 10.25	54(30-73)	0.957

MAP: mean arterial pressure, BP: blood pressure, INR: international normalization range min: minute

Categorical variables are expressed as numbers and percentages. For comparison between the two groups (USG and palpation), independent t-tests were used for normally distributed continuous variables, while Mann-Whitney U tests were applied for non-normally distributed variables. Chi-square tests were utilized to analyze categorical variables. A p-value < 0.05 was considered statistically significant.

A power analysis was conducted to determine the required sample size. Assuming an alpha level of 0.05, a power of 0.80, and based on expected differences in the number of attempts and procedure time between the two techniques, a sample size of 104 patients per group (208 patients in total) was determined to be sufficient to detect clinically significant differences between the groups.

RESULTS

We determined that the curriculum should cover tenIn the evaluation of catheterization techniques, a comparative analysis between palpation (n=104) and ultrasound-guided (USG) (n=104) procedures revealed several significant findings.

Demographic Characteristics:

The mean age of patients in the palpation group was 65.85 ± 14.94 years, with a median of 67 years (range: 24-96). The USG group's mean age was 66.69 ± 16.13 years, with a median of 68 years (18-93). The difference in age between the two groups was not statistically significant (p = 0.511). The distribution of males and females differed significantly between the palpation and USG groups (n=38 vs. n=66, p=0.018). Patients' height (p = 0.033) and BMI (p=0.004) showed a significant difference between the palpation and USG groups, while no significant differences were observed in weight (p=0.580, Table 1).

Catheterization Parameters:

The number of attempts for catheterization was significant between the two groups (2.36 ± 1.18 vs. 1.63 ± 0.83 attempts, p<0.001). Processing time was significantly shorter in the USG group (7.14 ± 2.42 vs. 11.83 ± 4.45 minutes, p<0.001, Table 1).

Hemodynamic Parameters:

Mean Arterial Pressure (MAP), Systolic Blood Pressure (SBP), and Diastolic Blood Pressure (DBP) of the patients did not show statistically significant differences between the two groups (p>0.05).

Laboratory Values:

The selection of ultrasound guidance for patients with higher INR levels was driven by clinical considerations to enhance patient safety. USG is known to reduce complications, particularly the risk of hematoma and excessive bleeding, which are of more significant concern in individuals with elevated INR. Significant differences were observed in the International Normalized Ratio (INR) (p = 0.004) between the palpation and USG groups. The USG group had a higher INR (1.23 ± 0.26) than the palpation group (1.14 ± 0.25). Hemoglobin, platelet count, albumin, and total protein levels did not show significant differences between the two groups (p > 0.05, Table 1).

Procedural Outcomes and Medical History:

The USG group demonstrated a significantly higher rate of success on the first attempt (p<0.001)

Table 2. The comparison of categorical variables between the palpation and the USG technique used for arterial cannulation.

	Palpation (n=104)	USG (n=104)	p
Male/Female	38/66	55/49	**0.018**
First attempt, n (%)	34 (32.7)	62(59.6)	**<0.001**
Complication, n (%)	33 (31.7)	17 (16.3)	**0.009**
Inotropic agent requirement, n (%)	50 (48.1)	61 (58.7)	0.126
PAD History, n (%)	9 (8.7)	13 (12.5)	0.367
CHF History, n (%)	32 (30.8)	34 (32.7)	0.776

USG: ultrasound, PAD: peripheral artery disease, CHF: congestive heart failure

and a lower rate of complications (p=0.009) compared to the palpation group (Table 2).

There were no significant differences in inotropic agent requirement, peripheral artery disease (PAD) history, and Congestive Heart Failure (CHF) history between the two groups (p>0.05, Table 2).

DISCUSSION

In our daily intensive care practice, arterial cannulation plays an important role, and arteries such as the radial and dorsalis pedis are the vessels that are frequently intervened.[6] The dorsalis pedis artery proceeds as a continuation of the anterior tibial artery in front of the ankle joint. It then descends as a deep plantar artery and completes the plantar arch [7,8]

Our study showed that the total operating time of patients undergoing ultrasound and arterial canulation was significantly shorter than that of patients under palpation. Similarly, Bicak et al.[9] and Anand et al.[10] report that the procedure under the ultrasound was significantly shorter. Shiver et al.[11] conducted a comparative study on arterial cannulation procedures, specifically ultrasound and palpation. The study had 60 patients and focused on determining the shorter length of ultrasounds. However, Bhattacharjee et al.[12] reported no notable disparity in processing time between the two methodologies.

Our study found that patients who underwent cannulation using the USG approach had a greater success rate on their initial attempt and required fewer total attempts. According to a study by Yeap et al.[13], using the USG method necessitates fewer surgical procedures. Bruzoni et al.[14] conducted a study on 150 pediatric patients and saw a decrease in ultrasound surgical procedures.

The initial ultrasonography trial demonstrated a superior success rate in research conducted by Ueda et al.[15] involving 749 individuals. In our investigation, we also discovered that with the USG procedure, the success rate was higher in the first attempt. In contrast to our study, Chanthawong et al.[16] reported comparable success rates in the initial effort when comparing ultrasonography and palpation techniques in a sample of 80 patients.

Our research has demonstrated a marked decrease in the incidence of complications when ultrasound is used for cannulation. Concurrently with our investigation, Oulego-Erroz et al.[17] and Souza et al.[12] demonstrated decreased complications using the USG approach in a cohort of 354 patients. An analysis of seven trials in the literature involving a total of 558 patients revealed that the incidence of hematoma was markedly reduced in arterial cannulation operations when ultrasound guidance (USG) was employed.[18] Zhao et al.[19] analyzed 19 trials, including 3,220 patients. Their findings indicate that ultrasound-guided arterial cannulation operations have much lower complication rates than palpation procedures.

In the study conducted by Sung et al.[20], 160 geriatric cases were examined. As a result of the study, the success rate in the first attempt in the arterial cannulation procedure performed on the radial artery with the ultrasound technique was higher than the palpation technique, and fewer complications were detected in the procedures performed with the ultrasound technique.

The groups did not exhibit any notable disparities in terms of the rates of inotropic need, average arterial pressure, peripheral artery disease, and heart failure. No significant differences were observed in the laboratory measurements of total protein (g/L), albumin (g/L), hemoglobin (g/dL), and platelets (10^3/μL). The USG group exhibited elevated INR levels, showing that USG was favored for individuals with

a higher risk profile. Although patients with higher INR values were more likely to undergo USG, this approach did not introduce bias into the study, as group assignments were determined randomly. The retrospective nature of data analysis ensured that comparisons between the palpation and USG groups remained valid, with no deliberate preference or bias influencing the results.

CONCLUSION

This study highlights that ultrasound guidance (USG) is safer, faster, and more efficient than palpation, especially when cannulating the dorsalis pedis artery. The preference for USG, particularly in patients with elevated INR, helps minimize complications such as hematomas. These findings suggest that USG should be preferred for arterial cannulation procedures to enhance success rates and reduce risks, especially in more challenging cases.

Limitations

This study has some limitations. First, operator dependence can affect the success of ultrasound-guided cannulation. Second, variability in the availability of ultrasound machines may limit the generalizability of the findings. Third, ensuring homogeneous patient selection was challenging, which could introduce some variability in the results.

We acknowledge the importance of diabetes mellitus (DM), Buerger's disease, and other peripheral arterial diseases that may impair vascular health and potentially impact the success of arterial cannulation. However, the study design did not include these conditions to maintain a focused analysis of parameters directly related to acute cardiovascular management and procedural outcomes.

In future research, we recommend expanding the scope to include additional vascular comorbidities, such as DM and Buerger's disease, to explore their impact on arterial access procedures further.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical Statement

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and received approval from Bursa Şehir Training and Research Hospital's Ethical Committee (Approval Number: 2023-18/10). The research was carried out on patients admitted to the Internal Medicine Intensive Care Unit at Bursa Şehir Training and Research Hospital, which is affiliated with the University of Health Sciences. Informed consent was obtained from all participants or their legal representatives prior to their inclusion in the study. All patient data were handled with strict confidentiality and in compliance with data protection regulations.

Authors' Contribution

Study Conception: NY; Study Design: NY, AE, NK; Supervision; NY, AE, NK; Funding: NY, AE, NK; Materials: NY, AE; Data Collection and/or Processing: NY, AE; Analysis and/or Data Interpretation: NK; Literature Review: ANY, NK; Critical Review: NY, AE, NK; Manuscript preparing: NY, NK.

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