Original Article

Comparison of two ultrasound-guided techniques for radial arterial cannulation in adults - Observational cross-sectional study

Safiya Sherrin M K, Paul O Raphael, Lini Chacko
Department of Anaesthesiology, Amala Institute of Medical Sciences, Thrissur, Kerala, India

Address for correspondence: Dr. Safiya Sherrin M K, Oasis, Viswas Kattachira Road, P.O. B P Angadi, Tirur, Malappuram District, Kerala - 676 102, India. E-mail: safiyasherrin01@gmail.com

Submitted: 12-Jul-2022
Revised: 15-Feb-2023
Accepted: 24-Feb-2023
Published: 10-Apr-2023

Access this article online
Website: www.ijaweb.org
DOI: 10.4103/ija.ija_597_22
Quick response code

ABSTRACT

Background and Aims: Short axis, out of plane (SAOOP) and long axis, in-plane (LAIP) are two approaches employed under ultrasound-guided radial arterial cannulation. Dynamic needle tip positioning (DNTP) is a recently introduced approach which integrates the features of both. **Methods:** A total of 114 adult patients from American Society of Anaesthesiologists (ASA) I-IV were studied in this hospital-based cross-sectional study after getting Institutional Ethical approval, CTRI registration and prior written informed consent. The primary objective was to compare the success rates among LAIP and DNTP techniques. The radial arterial diameter and its depth were correlated to the success rates in both. Statistical analysis was done using SPSS version 23.0. **Results:** Success rates were similar in both (*P* value-0.094). Ultrasonographic location time (in seconds) was shorter in DNTP (4.351 ± 0.9727) compared to LAIP (7.140 ± 1.0763) (*P* value-0.0001). The mean overall diameter and depth of radial artery (in mm) were found to be 2.36 ± 0.02 and 2.51 ± 0.12, respectively. Pearson's correlation coefficient between cannulation time and diameter was found to be -0.602 (*P* value-0.0001) and with depth of the radial artery was 0.034 (*P* value 0.723). **Conclusion:** The success rates were similar in both techniques. Ultrasonographic location time of the radial artery was more in LAIP although cannulation time was similar in both. Cannulation time decreased with an increase in the diameter of radial artery but was unaffected by the depth of the radial artery.

Key words: Artery, cannulation, catheterization, radial, ultrasound

INTRODUCTION

Arterial cannulation is the benchmark technique for monitoring blood pressure in patients with haemodynamic instability and for easy access of repeated blood samples for arterial blood gas analysis.[1,2] Currently, ultrasound-guided radial arterial cannulation is preferred over the conventional palpation or landmark technique due to increased success rates, lower incidence of complications and better acceptability among patients.[1,3,4]

There are primarily two techniques of radial arterial cannulation under ultrasound, viz. Short axis, out of plane technique (SAOOP) and Long axis, in plane technique (LAIP). Both have its own characteristic set of advantages and disadvantages. The advantages of SAOOP comprise of better appreciation of relevant anatomy including vessels, nerves and vein and various associated anomalies whereas, LAIP provides good visualization of needle tip and shaft. Dynamic needle tip positioning technique (DNTP) is a novel and advanced technique that combines the advantages of both the techniques.[5,6]

In the beginning, use of the DNTP technique reportedly resulted in better peripheral venous cannulation

How to cite this article: Safiya Sherrin MK, Raphael PO, Chacko L. Comparison of two ultrasound-guided techniques for radial arterial cannulation in adults – Observational cross-sectional study. Indian J Anaesth 2023;67:376-81.

success rates when compared to LAIP and was used later for radial arterial cannulation.[7]

In this study, our primary objective was to compare the success rates among these two groups, viz. DNTP and LAIP, in adults requiring radial arterial cannulation. Our secondary objectives were to calculate the magnitude of radial arterial diameter and depth from the skin and to correlate both to the success rates.

METHODS

After getting the hospital's Institutional Ethics Committee (IEC) approval, Clinical Trial Registry of India (CTRI) registration CTRI Number - CTRI/2020/09/027757, Registered on: 11/09/2020 and prior written informed patient consents for participation in the study and use of the patient data for research and educational purposes, this hospital-based observational study was conducted over a period of 24 months (November 2018 to October 2020) in a tertiary care medical college hospital in South India This study was conducted in accordance with the principle of decleration of Lelsinki, 2013. A total of 114 adult patients of either sex (male and female), from 18 to 90 years age, classified under American Society of Anaesthesiologists (ASA) physical status I-IV and requiring radial arterial cannulation were included. Exclusion criteria included evidence of inadequate ulnar collateral blood supply on modified Allen's test, history of radial artery cannulation in the preceding 30 days, patients with peripheral vascular disease, obese patients with body mass index (BMI) >35 kg/m^2 and patients with cardiorespiratory collapse. Unconsented and uncooperative patients were excluded along with patients with psychiatric illnesses and communication difficulties. Consecutive sampling was employed, and the patients were assigned into two groups of 57 patients each. Group A was DNTP, and Group B was LAIP.

Radial arterial cannulation was performed by anaesthesiologists with 5 or more years of experience in ultrasound-guided radial arterial cannulation. The possibility of blinding was prevented by the intrinsic nature of the study. Upon shifting the patients to the operation theatre, intravenous access was secured, standard monitoring was done, and baseline parameters were documented before the procedure as per hospital standard of care. Constant temperature range (22 ± 1°C) and recommended humidity (70%) were maintained inside operation theatre complex. The patient's upper limb was abducted at right angle from the body, and the wrist was stabilized at about 45 degrees dorsiflexion by placing a 100 ml saline bottle under it to fix the patient's hand out of the way of the anaesthesiologist's hand. The volar aspect of the wrist and ultrasound probe was then prepared with 2% chlorhexidine solution. The ultrasound gel was applied over the probe by an assistant and was then covered with sterile cover by the anaesthesiologist under strict aseptic precautions as per hospital standard of care. The ultrasonographic location time of the radial artery (USG time) was measured from the time of contact of ultrasonographic hockey stick probe L8 18i with frequency range 8–18 MHz [Venue 40 GE™ (General Electric) healthcare] portable ultrasound probe and location of the artery under ultrasound. Local anaesthesia was given with subcutaneous infiltration of 1 ml of 2% plain lignocaine over the artery and 20 gauge arterial catheter (BD™ Arterial Cannula) was used for both the techniques.

In LAIP, upon localizing the radial artery in short-axis view, the probe was turned around 90° to get the longitudinal view of the artery while keeping the image of the artery at the centre of the ultrasound image always. Arterial cannula was inserted at a 30°–45° angle with skin. Backflow of blood into the needle confirmed the needle's entry into the artery. The needle angle was then reduced to 15–30°, and the needle was then further advanced maximally inside the arterial lumen under real-time ultrasound guidance until the cannula tip was fully in the lumen while avoiding counter puncture of the radial artery under real-time ultrasound guidance. The needle was then taken out, and the cannula was threaded into the radial artery once free flow of arterial blood is visualized from the cannula.

In DNTP, the arterial cannula was inserted through the skin at a 30°–45° angle. Upon seeing the needle tip inside the arterial lumen, the angle of needle entry was reduced to 15°–30° with skin. The ultrasound probe was then moved proximally around 2 mm until the needle tip just vanished from the ultrasound view. The needle tip was then advanced couple of millimetres at a time until the tip was seen again on the ultrasound image. The needle was then further advanced maximally inside the arterial lumen under real-time ultrasound guidance while avoiding counter-puncture of the radial artery. The cannula was threaded into the radial artery once free flow of arterial blood is visualized from the cannula.

Thus, for both the techniques, the movement of the needle–cannula complex was similar but in LAIP, the probe was held fixed in longitudinal position, whereas in DNTP, the probe was held in short-axis position and serial cross-sectional images of the artery were taken to insert the radial arterial cannula. For both the techniques, the radial arterial cannula was then secured in place and arterial blood pressure was monitored with a connected arterial pressure transducer.

First pass success rate was defined as successfully obtaining a free flow of arterial blood through the radial arterial cannula in a single attempt. Ultrasonographic location time (A) was defined as the time from the probe touching the skin to the visualization of the radial artery in short axis for DNTP and in long axis for LAIP. Cannulation time (B) was defined as the time from probe location to free flow of arterial blood from the radial artery cannula. It included time spent in redirections and repeated attempts. Total time (C) was defined as the sum of ultrasonographic location time (A) and cannulation time (B). Each separate skin punctures were defined as separate attempts at cannulation. The complications of each procedure, viz. haematoma, arterial occlusion and thrombosis of the forearm, were also documented for 24 hours, if any. All variables were kept readily measurable mathematical parameters like distance (in millimetres) and time (in seconds) to avoid inter- and intra-observer bias. Patients were followed up for 24 hours to pick up complications due to the procedures.

The sample size of 57 patients in each group was ascertained based on a previous study that showed a first-pass success rate of 51% with SAOOP and 76% with LAIP approach of radial artery cannulation. This was a two-tailed study.[1] Alpha error was fixed at 5 percent and power at 80 percent.

SPSS version 23.0 was used for statistical analysis. We estimated the effect of the cannulation method on the first pass rate, overall success rate and number of attempts using Chi-square test for categorical variables. Data are presented as mean ± SD. Two-sample independent *t*-test or Mann–Whitney U-test, wherever appropriate, was used to gauge the effect of cannulation method on the cannulation time. We also correlated the ultrasonographic location time of the radial artery, cannulation time and total time of the procedure to the radial arterial diameter and distance of the radial arterial anterior wall from skin using Pearson's correlation. P value < 0.05 was recorded as statistically significant.

RESULTS

A total of 114 patients participated in the study. Inclusion criteria, exclusion criteria and sample size calculations were done to determine the study participation. Fifty-seven patients were present in both DNTP and LAIP groups. All patients were included for analysis [Figure 1].

The mean age (in years) in DNTP was 61.32 ± 11.76 and in LAIP was 56.82 ± 13.51 (P value > 0.05). Number of males and females in DNTP were 33 and 24, respectively(P value > 0.05), and number of males were 32 and females were 25 in LAIP group.

Mean BMI (in kg/m^2) was 23.564 ± 3.956 in DNTP and 24.002 ± 4.678 in LAIP. P value of ASA distribution across the two groups was 0.474. Mean systolic BP (in mm Hg) in DNTP was 139.825 ± 24.644 and in LAIP, 139.193 ± 21.776. Mean diastolic BP (in mm Hg) was 78.281 ± 16.287 in DNTP and 78.544 ± 14.225 in LAIP. Mean heart rate (in beats per minute) was 82.193 ± 14.986 in DNTP and 84.404 ± 14.444 in LAIP. There were no statistically significant differences in BMI distribution, ASA grades and haemodynamic parameters between the two groups (P value > 0.05).

Mean USG time (in seconds) in DNTP was 4.351 ± 0.972 and 7.140 ± 1.076 in LAIP. Mean cannulation time (in seconds) was 48.491 ± 8.124 in DNTP and 49.439 ± 7.812 in LAIP. Mean total time (in seconds) was 52.895 ± 8.072 in DNTP and 56.579 ± 7.759 in LAIP. Ultrasonographic location time of the radial artery (USG time) and total time were significantly higher in LAIP than DNTP (P value < 0.05), whereas the cannulation time was found to be similar in both the techniques (P value > 0.05) [Table 1].

Mean depth of radial artery (in mm) was 2.37 ± 0.31 in DNTP, 2.35 ± 0.30 in LAIP and 2.36 ± 0.30 in the Combined group. Mean diameter of radial artery (in mm) was 2.50 ± 0.12 in DNTP, 2.52 ± 0.12 in LAIP and 2.51 ± 0.12 in the Combined group. No statistically significant differences were recorded between the depth (mm) and diameter of the radial artery (mm) in both the groups as the P value is greater than 0.05 [Table 2].

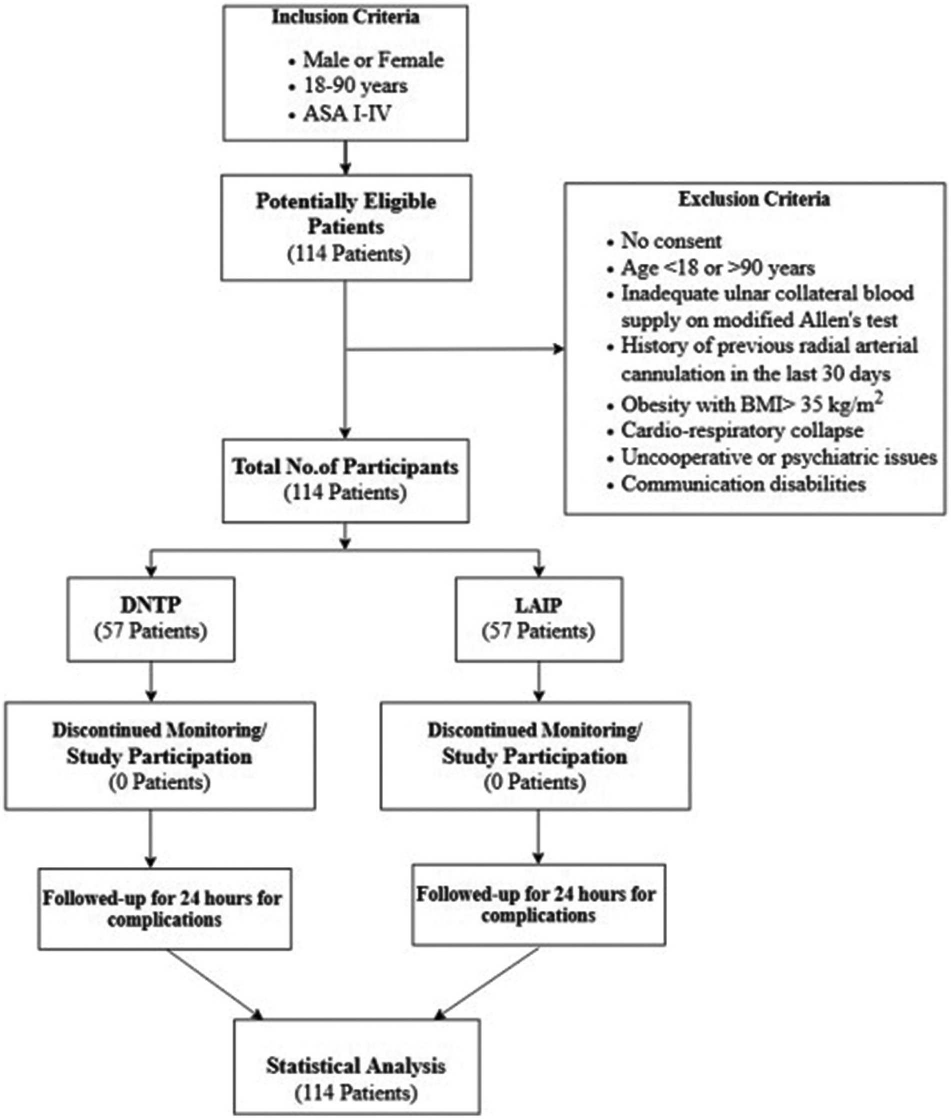

Figure 1: Study flow - STROBE

Table 1: Comparison of times in both the groups

Group	Mean	Std. deviation	*P* (Student's *t*-test)
USG time (s)			
DNTP	4.351	0.972	0.0001
LAIP	7.140	1.076	
Cannulation time (s)			
DNTP	48.491	8.124	0.527
LAIP	49.439	7.812	
Total time (s)			
DNTP	52.895	8.072	0.014
LAIP	56.579	7.759	

P value of Chi-squares for first pass success rates, number of attempts and number of cannulas were 0.094, 0.940 and 0.238, respectively [Table 3].

Cannulation time and total time had negative correlations with diameter of radial artery ($P < 0.05$), whereas USG time had no correlation with the diameter of radial artery in both the methods and in Combined group ($P > 0.05$) while depth of the radial artery had no correlation with USG time, cannulation time or total time of the procedure in both the methods ($P > 0.05$) [Table 4].

Chi-square test was done for haematoma, arterial occlusion and thrombosis in both the methods and were comparable in the two groups. ($P > 0.05$) [Table 5].

DISCUSSION

Among the two techniques, the short-axis technique provided a clear cross-sectional view of the needle and anatomical structures including arteries, nerves and veins during arterial cannulation. On the other hand, long-axis technique provided clear visualization of the needle tip and shaft and enhanced the success rates of cannulation post-puncture, but it also required better hand-eye coordination and more experience.[8,9]

The demographic data (age, gender and BMI), the baseline haemodynamic parameters (heart rate, systolic and diastolic blood pressure) prior to cannulation and diameter and depth of the radial artery from the skin were comparable in both the groups. These parameters could affect the ultrasonographic location time and cannulation time. A few studies noted higher difficulty levels in elderly and cardiac patients in LAIP.[10,11]

Table 2: Comparison of depth and diameter of the radial artery in dynamic needle tip positioning technique and long-axis in-plane technique

Group	Mean	Std. deviation	*P* (Student's *t*-test)
Depth (mm)			
DNTP	2.37	0.31	0.695
LAIP	2.35	0.30	
Combined	2.36	0.30	
Diameter (mm)			
DNTP	2.50	0.12	0.456
LAIP	2.52	0.12	
Combined	2.51	0.12	

Table 3: Comparison of first pass success rates, number of attempts and number of cannulas used in both the groups

	Group		Total	*P* (chi-square test)
	Dynamic	Long axis		
First pass success rates				
Yes	55	57	112	0.094
No	2	0	2	
Total	57	57	114	
Number of attempts				
Yes	55	57	112	0.940
No	2	0	2	
Total	57	57	114	
Number of cannulas used				
Yes	56	57	113	0.238
No	1	0	1	
Total	57	57	114	

We found that the ultrasonographic location time in LAIP was significantly longer because the probe had to be pivoted from short-axis to long-axis view to capture the whole artery corroborating with the findings made by a few other authors.[11-13] It was found crucial to place the artery in the midpoint of the screen always to increase the success rates. No statistically significant difference in the cannulation time was recorded between the two groups. Further, we found that depth of the artery had no correlation with the success rates in both the methods like in a previous study.[14] However, both cannulation time and total time proportionally decreased with increase in diameter of the artery in both probably because larger arteries allowed more margin of error and more room for manipulation of the needle.

Although statistically not significant, we did find higher rates of haematoma formation in DNTP technique. In cross-sectional view, needle shaft could be misinterpreted as the needle tip while the tip itself might have inadvertently punctured the posterior arterial wall causing complications such as haematoma in DNTP, whereas in LAIP technique, the path and tip of the needle were distinctly seen under real-time ultrasound guidance and hence, penetration of the posterior wall was prevented.[11,12,15]

Remarkably, LAIP technique may have given an illusion of needle shaft lying inside the arterial lumen although it might have been actually lying just horizontally parallel to the artery.[16] While this might not pose difficulties in cannulations of bigger vessels such as subclavian vein or internal jugular vein, it could increase failure rates in smaller vessels such as radial artery. Further, LAIP got even more challenging in patients with narrowed arterial lumen, in multiple attempts, with increased arterial tortuosity and anatomical variations. Use of multiple operators, inability to introduce blinding due to nature of the study and inadequate experience in DNTP due to it novelty can be considered as

Table 4: Correlation coefficients in both groups

	Correlation coefficient in Combined group		Correlation coefficient in DNTP		Correlation coefficient in LAIP	
	Correlation coefficient	*P*	Correlation coefficient	*P*	Correlation coefficient	*P*
Diameter and USG time	0.119	0.208	0.103	0.444	0.108	0.426
Diameter and cannulation time	-0.602	0.0001	-0.413	0.001	-0.823	0.0001
Diameter and total time	-0.566	0.0001	-0.403	0.002	-0.814	0.0001
Depth and USG time	0.018	0.847	-0.102	0.449	0.259	0.051
Depth and cannulation time	0.03	0.75	-0.02	0.884	0.09	0.505
Depth and total time	0.034	0.723	-0.032	0.811	0.127	0.348

Table 5: Comparison of complications in both the groups

	Group		Total	*P* (Chi-square test)
	Dynamic	Long axis		
Haematoma				
Yes	1	0	1	>0.05
No	56	57	113	
Total	57	57	114	
Arterial occlusion				
Yes	0	0	0	>0.05
No	57	57	114	
Total	57	57	114	
Thrombosis				
Yes	0	0	0	>0.05
No	57	57	114	
Total	57	57	114	

limitations of the study. Large-scale randomized control trials and meta-analyses can validate the study on a larger scale.

CONCLUSION

In this study, the first pass success rates were similar in both the newly described ultrasound guided DNTP technique and LAIP for ultrasound-guided radial arterial cannulation. Hence, either of the two approaches may be preferred for radial arterial cannulation without compromising on the success rate of the procedure. Further, both ultrasonographic location time of the artery and cannulation time were found to decrease proportionally in both the groups with increase in the magnitude of the radial artery. However, depth of the radial artery had no effect on either ultrasonographic location time or cannulation time of the radial artery.

Acknowledgements

All the patients, their attendants, anaesthesia technicians, staff nurses who helped in the smooth conduct of the study and colleagues and fellow postgraduate residents for their valuable suggestions and inputs.

Declaration of patient consent

The authors attest that they have obtained all appropriate patient consent forms in which the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their identity will not be published or revealed in any manner, and all efforts will be made to ensure confidentiality, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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