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Original Research Article

A Comparative Study of Ultrasound Guided Dynamic Needle Tip Positioning Versus Angle Distance Technique for Radial Artery Cannulation in Adult Patients Planned For Surgery

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Abstract

Aims and Objectives: This study was to ascertain the improvement in success rates of first-attempt cannulation of the radial artery using ultrasound guided dynamic needle tip positioning technique (DNTP) versus angle distance (AD) technique.

Material and Methods: A total 70 adult patients scheduled for elective surgery, after written informed consent was enrolled after ethical approval. The patients older than 18 years, ASA grade I-IV and positive modified allen's test was included. Hemodynamically unstable, patient refusing for study, age less than 18 years, and patients with blocked targeting artery was excluded. Patients was assigned for ultrasound guided dynamic needle tip positioning (DNTP) group and angle distance (AD) group (35 patients in each group) using the sealed-envelope method. The anaesthesiologist who was conduct the cannulation procedure know the allocation of patients. The patients were blinded to the allocation.

Results: First-pass success without posterior wall puncture was present 80% in group AD and 48.66% in group DNTP. First-pass success rate was present 62.9% in group AD and 28.6% in group DNTP. 10 min overall success rate was present 97.1% in group AD and 88.6% in group DNTP. Cannulation time was 163.26 second in group AD and 429.31 second in group DNTP. Posterior wall puncture was present 20% in group AD and 51.4% in group DNTP. One puncture was present 62.9% in group AD and 28.6% in group DNTP. Two puncture was present 8.6% in group AD and 48.6% in group DNTP. Three puncture was present 22.9% in group AD and 14.3% in group DNTP. Four puncture was present 5.7% in group AD and 8.6% in group DNTP. 600s was 163.26 second in group AD and 429.31 second in group DNTP.

Conclusion: The first-pass success rate, with or without arterial posterior wall puncture was more with AD technique compared to DNTP technique. There were no significant difference in the 10-min overall success rate between the DNTP and AD groups. However, the cannulation time was shorter and the posterior wall puncture rate was lower in the AD group than in the DNTP group. The appropriate technique should be applied depending on the specific clinical situation.

Keywords: Radial Artery Cannulation, USG, DNTP, AD, First Pass Success Rate.

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Introduction

Arterial cannulation is a well-known invasive procedure performed in operating rooms and intensive care units. It is frequently done in patients requiring repeated blood sampling and hemodynamic monitoring. [1] Multiple sites are available for arterial cannulation. However, the radial artery is usually preferred due to its superficial course with consistent anatomy and low complication rates, such as permanent ischemic complications (0.09%). [2] However, cannulation is generally trickier in the pediatric population with the prolonged time required and multiple attempts at times. [3] Complications commonly associated with arterial cannulation nerve injury are hematoma, infection and vasospasm. [4] However, these complications are considerably reduced by the efficient use of ultrasound for arterial cannulation rather than the palpation method, a point proved by multiple studies. [5] USG visualization can be improved or impaired depending on the parameters of the USG device itself and the individual characteristics of the needle. [6] In addition, the angle of the needle in relation to the sound beam and the use or not of specific visualization software can also interfere with the quality of the images. [7]

At the time of puncture, the needle will form an angle in relation to the USG beam and in relation to the surface to be punctured. Since it is a highly reflective structure, when the waves produced by the probe hit the needle close to a right angle, a large proportion return to the probe, generating a good quality image. However, as the puncture angle becomes steeper in relation to the surface, the waves are reflected, but do not return to the probe, forming a worse quality image or even making the needle invisible. [8]

The resources available in the USG settings, the characteristics relevant to the composition of the needle (material, diameter, and length), and also the puncture angle in relation to the surface all affect reflection of the waves and change the quality of the image. [9] Ultrasound can be used in two orientations with their specific advantages and disadvantages. One of these is the short axis (out of plane) technique which provides better visualization and appreciation of vessel and surrounding structures. On the other hand, in the long axis (in the plane) approach, the needle shaft is visible throughout the course. [10]

Two different techniques are mainly applied in clinical practice: the long axis in-plane (LA-IP) approach and the short axis out-of-plane (SA-OOP) approach. [11] In recent years, a modified version of the SA-OOP approach termed 'dynamic needle-tip positioning (DNTP)' was shown to be a better choice by integrating the advantage of both the SA-OOP and LA-IP approach. [12]

By frequently moving an ultrasound probe along the target blood vessel, the DNTP approach could provide an image of both the whole puncture route and surrounding tissue. In 2021, a meta-analysis, including six randomized controlled trials (RCTs) and one retrospective study, indicated that the DNTP method was better in terms of first-attempt success, overall success, and complications than conventional palpation in arteriovenous puncture. [13]

The traditional short-axis technique, that is, the angle-distance (AD) method, is accurate in terms of positioning and is convenient for novices to master. Earlier studies have suggested that using the AD technique can significantly improve the success rate of cannulation.

However, despite the advantages of the short-axis technique, such as accurate positioning of the puncture point and visualization of the relevant perivascular structures, posterior wall puncture of the target artery might not be avoided.[14,15]

The rationale of this study was to ascertain the improvement in success rates of first-attempt cannulation of the radial artery using ultrasound guided dynamic needle tip positioning technique (DNTP) versus angle distance (AD) technique.

Materials and Methods

Study Area: Department of Anesthesiology at Santokbha Durlabhji Memorial Hospital and Medical Research Institute, Jaipur after taking approval from institutional ethical committee.

Study Sample: Sample size was calculated at 80% study power and alpha error of 0.05 expecting 84% with DNTP technique and 52% with AD technique in reference study. (Bai et al) [26] So sample size is calculated by using the below formula for hypothesis testing for two independent population proportion. Where, Standard normal deviate for Type 1 error (taken as 1.96 for 95% confidence level or alpha error 0.05), Standard normal deviate for Type 2 error (taken as 0.84 for 80% study power), P1 = P1 is proportion in group 1 (P1= 0.84), P2=P2 is proportion in group 2 (P2= 0.52), P = (P1 + P2)/2

$$N = \frac{[Z_{1-\alpha/2}\sqrt{2P(1-P)} + Z_{1-\beta}\sqrt{P_1(1-P_1)+P_2(1-P_2)}\,]^2}{(P_1 - P_2)^2}$$

Following above assumptions, 32 patients in each group are required as sample size for present study which was further enhanced and rounded off to 35 patients in each group as final sample size for present study was expecting 5% attrition.

Study duration: A prospective, single blinded observational study was performed after ethical approval within a period of 12 months or till sample size is achieved, whichever was earlier.

Inclusion criteria were - patients older than 18 years of age, having ASA (American society of anaesthesiology) grading I –IV, patients planned to undergo elective abdominal surgery under general anaesthesia and needed arterial line insertion and also modified Allen's test should be positive.

Exclusion criteria were - patient refusal, patients less than 18 years of age, patients with hemodynamic instability, and contraindication for peripheral arterial puncture or catheterization, and a blocked or embolized target vessel determined by ultrasound assessment.

Method of Selection: By computer-generated numbers provided in sealed opaque envelopes to either the dynamic needle tip positioning (DNTP) or angle-distance (AD) group.

Intervention and Grouping: Group USG DNTP; n=35 and Group USG AD; n=35

Methods

A total 70 adult patients scheduled for elective surgery, after written informed consent was enrolled after ethical approval. The patients older than 18 years, ASA grade I-IV and positive modified allen's test was included. Hemodynamically unstable, patient refusing for study, age less than 18 years, and patients with blocked targeting artery was excluded. Patients was assigned for ultrasound guided dynamic needle tip positioning (DNTP) group and angle distance (AD) group (35 patients in each group) using the sealed-envelope method. The anaesthesiologist who was conduct the cannulation procedure know the allocation of patients. The patients were blinded to the allocation.

Basic monitors were used like Pulse oximetry, Electrocardiography and non-invasive blood pressure. Blood pressure cuff was placed in the opposite side of radial artery cannulation arm. After induction of anaesthesia with intravenous midazolam (0.025 -0.05 mg/kg), fentanyl (1-1.5 mcg/kg), propofol (1.5-2 mg/kg) and Atracurium (0.5 mg/kg), patients were intubated. Isoflurane (1.2- 1.5 %), oxygen and air (50%:50%) was used for maintenance of anaesthesia and radial artery cannulation was performed. Artery cannulation was done by same anaesthesiologist who had previously performed >100 ultrasound-guided arterial catheterizations in adult patients, using the ultrasound imaging system (Sonosite M Turbo, India Pvt. Ltd.) with a high-frequency probe (5–13 MHz). All of the arterial cannulation procedure was performed by the same anaesthesiologist who skilled in 2 methods (USG guided DNTP and AD techniques) using a 20G arterial cannula (BD Arterial Cannula, Becton Dickinson Infusion Therapy System, Utah 84070, USA).

A small roll was placed under the wrist, and the palm of the hand was taped to keep the patient's arm slightly extended. The insertion site was disinfected with povidone iodine solution. Sterile technique including sterile gloves, operating towels, and ultrasonic probe covers were used as per the standard protocol for arterial catheterization.

The vitals of patients were maintained near to base line during arterial catheterization. For both techniques, a timer was started when the operator was ready to use the needle to pass through the skin and was stop when an arterial waveform appeared. If the cannulation time was taken longer than 10 minutes, the procedure was terminated, other techniques were used for arterial cannulation or non-invasive blood pressure will be monitored. In that case, the cannulation was recorded as 600 s.

While using DNTP technique, ultrasound probe was placed on radial artery in short axis view by keeping artery in centre of the ultrasound screen. The needle was inserted at 30° angle near to middle mark of the probe contacted the skin and advanced until the tip was visible on the screen. The probe was moved proximally, away from initial insertion point until the tip just disappear from the screen. Then, needle was readvanced until tip visible again. These steps were repeated until the needle tip visible in artery lumen. The cannula was inserted into the artery and the needle was removed.

While using AD technique, ultrasound probe was placed on radial artery in short axis view by keeping artery in centre of the ultrasound screen. Then, distance between probe and anterior wall of artery was measured and the same distance away from probe, needle was inserted at 45^{o} angle targeting the artery. Then the needle was advanced until blood appeared in the hub. The needle angle was decreased slightly while the catheter was advanced in the artery. The catheter was inserted into the artery only if blood continue to flow into hub. If insertion failed or the target missed, the needle insertion direction was adjusted according to the position of the needle tip.

Method of Measurement of Outcome of Interest: Baseline data was collected for each patient: sex, age, height, body mass index, Systolic blood pressure, diastolic blood pressure, mean blood pressure, heart rate just before the procedure and during procedure, Any history of hypertension, diabetes, coronary heart disease or smoking, surgery type, radial artery diameter and depth. The primary outcome was include first- pass success without posterior wall puncture. The secondary outcome was include first-pass success rate, the 10-min overall success rate, the cannulation time, posterior wall puncture and the number of skin punctures.

Definitions

First-pass success without posterior wall puncture is successful catheterization without vascular damage to the posterior wall.

First- pass success is successful catheterization on the first attempt regardless of vascular damage to the posterior wall. 10-min overall success is successful catheterization regardless of vascular damage to the posterior wall and without a limit on the number of punctures.

Cannulation time is interval between skin contact with the probe and confirmation of the arterial waveform on the monitor. Posterior wall puncture of radial artery is when the operator will see the needle passing the posterior wall or blood backflow appear then disappear while needle advancing.

The number of skin punctures is refers to the number of skin punctures that occurred during the whole cannulation procedure.

PICOT

- Population: Patients undergoing surgery requiring radial artery cannulation
- Intervention: Radial artery cannulation
- Comparator: Dynamic needle tip positioning and angle distance technique
- Outcome: First pass success rate
- Time: A period of 12 months or till sample size is achieved, whichever is earlier.

Statistical Analysis: The data was coded and entered into Microsoft Excel spreadsheet. Analysis was done using IBM SPSS (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 25 for Windows software program. Descriptive statistics included computation of percentages, means and standard deviations. The data were checked for normality before statistical analysis using Kolmogorov Simonov test. The unpaired t test (for quantitative data to compare two independent observations) was applied. The chi square test was used for qualitative data comparison of all clinical indicators. Level of significance was set at P≤0.05.

Observation and Results

A total 70 adult patients scheduled for elective surgery was included. Mean age for group AD was 47.77 year and for group DNTP was 45.31 year and showed no significant difference in between group AD and group DNTP. In group AD, 62.9% male and 37.1% female were included. And in group DNTP, 51.4% male and 48.6% female were included. Comparison of gender in between group AD and group DNTP was not statistically significant.

In group AD ASA I, ASA II and ASA III were included 28.6%, 42.9% and 28.6% respectively and in group DNTP ASA I, ASA II and ASA III were 48.6%, 28.6% and 22.9%. Comparison of ASA in both groups showed statistically non-significant result. Comparison of HR, SBP, DBP and MAP in between both groups showed statistically non-significant results.

Table 1: Comparison of radial artery diameter

		Mean	Std. Deviation	P value
Radial artery diameter (in cm)	AD	0.24	0.04	0.004 (S)
	DNTP	0.206	0.04	
Radial artery depth (in cm)	AD	0.23	0.06	0.108
	DNTP	0.21	0.06	

Mean radial artery diameter was 0.24cm in group AD and 0.206cm in group DNTP. Comparison of radial artery diameter in between both groups showed statistically significant results. Mean radial artery depth was 0.23cm in group AD and 0.21cm in group DNTP. Comparison of radial artery depth in between both groups showed statistically non-significant results.

Table 2: Comparison of first-pass success without posterior wall puncture

			First-Pass Success Without Posterior Wall Puncture		Total
			NO	YES	
Groups	AD	N	7	28	35
		%	20.0%	80.0%	100.0%
	DNTP	N	18	17	35
		%	51.4%	48.6%	100.0%
Total		N	25	45	70
		%	35.7%	64.3%	100.0%

P value=0.006 (S)

First-pass success without posterior wall puncture was present 80% in group AD and 48.66% in group DNTP. Comparison of first-pass success without posterior wall puncture in both group showed statistically significant results.

Table 3: Comparison of first-pass success rate

			First-Pass Success Rate		Total
			No	Yes	
Groups	AD	N	13	22	35
		%	37.1%	62.9%	100.0%
	DNTP	N	25	10	35
		%	71.4%	28.6%	100.0%
Total		N	38	32	70
		%	54.3%	45.7%	100.0%

P value=0.004 (S)

First-pass success rate was present 62.9% in group AD and 28.6% in group DNTP. Comparison of first-pass success rate in both groups showed statistically significant results.

Table 4: Comparison of 10 min overall success rate

			10-Min Overall Success Rate		Total
			No	Yes	
Groups	AD	N	1	34	35
		%	2.9%	97.1%	100.0%
	DNTP	N	4	31	35
		%	11.4%	88.6%	100.0%
Total		N	5	65	70
		%	7.1%	92.9%	100.0%

P value=0.16

10 min overall success rate was present 97.1% in group AD and 88.6% in group DNTP. Comparison of 10 min overall success rate in both groups showed statistically non-significant results. There was unsuccessful cannulation in 10 minutes in one patient in group AD and in four patients in group DNTP.

Table 5: Comparison of cannulation time in Seconds

	Mean	Std. Deviation	P value
AD	163.26	106.010	0.001 (S)
DNTP	429.31	123.105	

Cannulation time was 163.26 second in group AD and 429.31 second in group DNTP. Comparison of cannulation time in between groups showed statistically significant results.

Table 6: Comparison of posterior wall puncture

			Posterior Wall Puncture		Total
			No	Yes	
Groups	AD	N	28	7	35
		%	80.0%	20.0%	100.0%
	DNTP	N	17	18	35
		%	48.6%	51.4%	100.0%
Total		N	45	25	70
		%	64.3%	35.7%	100.0%

P value=0.006 (S)

Posterior wall puncture was present 20% in group AD and 51.4% in group DNTP. Comparison of posterior wall puncture in both groups showed statistically significant results.

Table 7: Comparison of number of skin puncture

			Number Of Skin Puncture				Total
			1	2	3	4	
Groups	AD	N	22	3	8	2	35
		%	62.9%	8.6%	22.9%	5.7%	100.0%
	DNTP	N	10	17	5	3	35
		%	28.6%	48.6%	14.3%	8.6%	100.0%
Total		N	32	20	13	5	70
		%	45.7%	28.6%	18.6%	7.1%	100.0%

P value=0.002 (S)

One puncture was present 62.9% in group AD and 28.6% in group DNTP. Two puncture was present 8.6% in group AD and 48.6% in group DNTP. Three puncture was present 22.9% in group AD and 14.3% in group DNTP. Four puncture was present 5.7% in group AD and 8.6% in group DNTP. Comparison of number of punctures in both groups showed statistically significant results.

Table 8: Comparison of 600s

	Mean	Std. Deviation	P value
AD	163.26	106.010	0.001 (S)
DNTP	429.31	123.105	

600s was 163.26 second in group AD and 429.31 second in group DNTP. Comparison of 600s between groups showed statistically significant results.

Discussion

Arterial catheterization for cardiac surgery is essential for the continuous invasive monitoring of arterial pressure and arterial blood sampling. The radial artery is most commonly used because of the low incidence of complications. [16] However, with palpation technique, cannulation of the radial artery can be challenging, even for experienced providers.

Numerous techniques have been described for insertion of catheters such as direct cannulation with an over the needle approach, modified Seldinger technique, the liquid stylet technique, pressure curve directed technique etc. [17] Utilizing a Doppler to aid in radial artery cannulation has been well described. [18]

Radial artery cannulation is generally accepted to be a low risk procedure.[19] One of the most important factor for failure of cannulation with direct technique was inability to advance the catheter even the needle appeared to be inside the artery, this problem may result from a tangential approach to the artery, tortuosity of the artery, or radial artery spasm. Another important cause is the impingement of the tip of the needle on the posterior wall. In this position a free flashback of blood will be obtained although the catheter is unable to pass the needle tip. However the guide wire catheter can be advanced into the artery even if the posterior wall impingement occurs. [20]

The angle of needle insertion in relation to the surface and consequently in relation to the beam of sound waves emitted by the ultrasound probe is very important for obtaining an adequate image. Punctures of superficial structures tend to have better visualization, since they penetrate the surface at an angle that is closer to perpendicular to the wave beam, reflecting more of the sound waves for image formation. At the same time, punctures of deeper structures that require a steeper puncture in relation to the surface tend to have a lower quality image, because there will be greater dispersion of sound waves, impairing image formation. [21]

In our study, mean age for group AD has 47.77 year and for group DNTP has 45.31 year. In group AD 62.9% male and 37.1% female were included. And group DNTP 51.4% male and 48.6% female were included. In group AD ASA 1, ASA 2, and ASA 3 were 28.6%, 42.9%, and 28.6% and in group DNTP ASA 1, ASA 2, and ASA 3 were 48.6%, 28.6% and 22.9% respectively. There is no significant difference in both group in demographic data. In Bai et al study, [26] there were 79 (60.3%) males and 52 (39.7%) females, and the average age was 58.27 ± 13.26 years. Grade I-II was 16 cases and grade III-IV was 50 cases in group AD Grade I-II was 17 cases and grade III-IV was 48 cases in group DNTP.

First-pass success rate was present 62.9% in group AD and 28.6% in group DNTP in our study. When compared to the DNTP method, the AD method decreased the number of punctures in the rear wall. Different ways have different pros and cons, which is why there was a big difference in the success rates of the two. Comparing out-of-plane ultrasound guided versus palpation for arterial catheterization has been done before. The traditional out-of-plane ultrasound-guided method, which is similar to our AD technique, has a first-pass success rate of 53% to 78%. , [22,23] Recently, researchers reported that a modified technique, the DNTP technique, has a first-pass success rate of 82%,[24] suggesting that the success rate was higher for the DNTP technique than the traditional AD method. In our study AD technique shows more first pass success rate compare to DNTP as AD technique is easier to learn compare to DNTP technique and out of plane technique were common use for vascular access that's another reason for more success in AD technique compare to DNTP technique.

In few studies first-attempt success rates with the DNTP technique in adult patients were 83% [1] and 95%. [25] Grandpierre et al,[26] showed that Ultrasound improved the first-try success rate for radial artery puncture in patients whose radial arteries were hard to get a blood gas study on because they couldn't be felt or had two failed punctures before. The use of ultrasound makes it easier to find the radial artery when other methods have failed. In our study, successful cannulation with one skin puncture was 62.9% in group AD and 28.6% in group DNTP. In clinical practice, we sometimes see patients whose blood doesn't clot easily. We worry that the artery puncture will break through the back wall and cause problems like a hematoma. There are two types of ultrasound-guided venous cannulation: in-plane and out-of-plane.[27] With in-plane technology, it is easy to see the needle's path from entry to placement of the catheter. This seems to help lower the risk of posterior vessel wall puncture. However, the person using this technology needs to be very good at ultrasound technology, which is more of an art and can be hard for beginners to learn. On the other hand, because the ultrasound beam's thickness can be measured, the long axis can sometimes show slice-thickness artefacts that make the cannula look like it's in the same plane as the very small radial artery, even when it hasn't been successful.[29,30]

In present study, Cannulation time was significantly less in group AD (163.26 second) than group DNTP (429.31 second). Recently, many clinical studies have demonstrated the superiority of ultrasound-guided arterial catheterization.

Several meta-analyses have shown that ultrasound guided methods are superior to palpation methods in adults, children, and even newborns. [31,32,33]

However, a meta-analysis found that ultrasound guidance did not increase the total success rate of radial artery cannulation, the reason for which may be related to the different ultrasound technology, patients population, operators experience.

In present study, radial artery diameter was 0.24 cm in group AD and 0.206 cm in group DNTP. Radial artery depth was 0.23 cm in group AD and 0.21 cm in group DNTP. There is significant difference seen in radial artery diameter in both groups. This may one of the reason of more success in AD technique as in AD group diameter of artery is more compare to DNTP technique. Another study [1] using ultrasound-guided dynamic tip localization for radial artery cannulation showed that the average diameter of the radial artery was 0.28 cm, with a first pass success rate of 83% and overall success rate of 89.3% in DNTP technique compare to traditional palpation technique, which was inconsistent with ours study.

This may be related to the number of operators and the different training and experience of the operators; 41 residents and faculty members performed radial artery cannulation, which may have reduced the success rate. According to the Tian et al study, it was estimated an optimal depth of more than 2.25mm was associated with an improved first-attempt success rate of DNTP-guided catheterization The reason was that the needle tip can be well-adjusted to puncture into the center when there was enough distance from the anterior arterial wall. In addition, the key to the success of DNTP is identifying the needle tip, hence, it's less likely to distinguish the hyperechoic needle tip from the similar subcutaneous tissues when they are close to each other. It was demonstrated that the depth of 2–4mm improved the success rates of conventional short-axis ultrasound-guided RAC in children younger than 3 years old. [36]

Limitations of study

There are several limitations to our trial. First, the ultrasound-guided arterial cannulation procedures were done by experience operator. Because of this, our data should not be used to judge other doctors. Second, Bias may be due to operator already use to out of plane technique.

The results might have been different if the sample size had been bigger. Third, the people who did the cannulations couldn't be blind to the process that was used. This could lead to bias because of what the person expects to happen. To avoid bias, though, different observers were not told about the cannulation process. Fourth, we couldn't incorporate the patients that are hemodynamically unstable and also we didn't include the pediatric group of patients so couldn't compare the difference between adult and pediatric groups.

Conclusions

The first-pass success rate, with or without arterial posterior wall puncture was more with AD technique compared to DNTP technique. There were no significant difference in the 10-min overall success rate between the DNTP and AD groups. However, the cannulation time was shorter and the posterior wall puncture rate was lower in the AD group than in the DNTP group. The appropriate technique should be applied depending on the specific clinical situation.

References

1. Kiberenge RK, Ueda K, Rosauer B. Ultrasound-Guided Dynamic Needle Tip Positioning Technique Versus Palpation Technique for Radial Arterial Cannulation in Adult Surgical Patients: A Randomized Controlled Trial. Anesth Analg 2018; 126(1): 120-26.
2. Liu L, Tan Y, Li S, Tian J. "Modified dynamic needle tip positioning" short-axis, out-of-plane, ultrasound-guided radial artery cannulation in neonates: a randomized controlled trial. Anesth Analg 2019; 129(1): 178-83
3. Jang YE, Kim EH, Lee JH, Kim HS, Kim JT. Guidewire-assisted vs. direct radial arterial cannulation in neonates and infants: A randomised controlled trial. Eur J Anaesthesiol 2019; 36(10): 738-44.
4. Kim SY, Kim KN, Jeong MA, Lee BS, Lim HJ. Ultrasound guided dynamic needle tip positioning technique for radial artery cannulation in elderly patients: A prospective randomized controlled study. PLoS One 2021; 16(5): e0251712
5. Wang J, Lai Z, Weng X, Lin Y, Wu G, Su J, et al. Modified longaxis in-plane ultrasound technique versus conventional palpation technique for radial arterial cannulation: A prospective randomized controlled trial. Medicine (Baltimore) 2020; 99(2):e18747
6. Sites BD, Brull R, Chan VW, Spence BC, Gallagher J, Beach ML, et al. Artifacts and pitfall errors associated with ultrasound-guided regional anesthesia. Part I: understanding the basic principles of ultrasound physics and machine operations. Reg Anesth Pain Med. 2007;32(5):412-8.
7. Lamperti M, Biasucci DG, Disma N, Pittiruti M, Breschan C, Vailati D, et al. European Society of Anaesthesiology guidelines on peri-operative use of ultrasound-guided for vascular access. Eur J Anaesthesiol. 2020;37(5):344-76

8. Chin KJ, Perlas A, Chan VW, Brull R. Needle visualization in ultrasound-guided regional anesthesia: challenges and solutions. Reg Anesth Pain Med. 2008;33(6):532-44
9. Takatani J, Takeshima N, Okuda K, Uchino T, Hagiwara S, Noguchi T. Enhanced Needle Visualization: advantages and indications of an ultrasound software package. Anaesth Intensive Care. 2012;40(5):856-60
10. Bhattacharjee S, Maitra S, Baidya DK. Comparison between ultrasound guided technique and digital palpation technique for radial artery cannulation in adult patients: An updated metaanalysis of randomized controlled trials. J Clin Anesth 2018; 47:54-59.
11. Franco-Sadud R, Schnobrich D, Mathews BK, Candotti C, Abdel-Ghani S, Perez MG, et al; SHM Point-of-care Ultrasound Task Force; Soni NJ. Recommendations on the Use of Ultrasound Guidance for Central and Peripheral Vascular Access in Adults: A Position Statement of the Society of Hospital Medicine. J Hosp Med. 2019;14(9):E1-E22.
12. Liu W, Tu Z, Liu L, Tan Y. Combined short- and long-axis method for internal jugular vein catheterization in premature newborns: A randomized controlled trial. Acta Anaesthesiol Scand. 2021;65(3):420-27
13. Shi J, Shen J, Xiang Z, Liu X, Lu T, Tao X. Dynamic Needle Tip Positioning versus Palpation and Ultrasound for Arteriovenous Puncture: A Meta-analysis. Ultrasound Med Biol. 2021;47(8):2233-42.
14. Shiver S, Blaivas M, Lyon M. A prospective comparison of ultrasound-guided and blindly placed radial arterial catheters. Acad Emerg Med. 2006; 13:1275–9.
15. Levin PD, Sheinin O, Gozal Y. Use of ultrasound guidance in the insertion of radial artery catheters. Crit Care Med. 2003; 31:481–4.
16. Hack WW, Vos A, Okken A. Incidence of forearm and hand ischaemia related to radial artery cannulation in newborn infants. Intensive Care Med. 1990;16(1):50–3.
17. Stirt JA. "Liquid stylet" for percutaneous radial artery cannulation. Can Anaesth Soc J. 1982;29(5):492- 93
18. Fukutome T, Kojiro M, Tanigawa K, Sese A. Doppler-guided 'percutaneous' radial artery cannulation in small children. Anesthesiology. 1988;69(3):434–5
19. Yildirim V, Ozal E, Cosar A, Bolcal C, Acikel CH, Kilic S, et al. Direct versus guidewire-assisted pediatric radial artery cannulation technique. J Cardiothorac Vasc Anesth. 2006;20(1):48-50
20. Yildirim V, Doganci S, Cinar S, Demirkilic U, Cosar A, Kurt E. Ultrasound-guided or direct cannulation of radial artery with guide-wire system in critically ill patients: A randomized comparison of two techniques. BMMR. 2008;11(4):163-67
21. Kline J. Reliable needle visualization during ultrasound guided regional and vascular procedures: a simple solution to steep angle echogenicity loss with any ultrasound system, based on target depth. Anesthesia eJournal. 2015;3(2):1-4.
22. Levin PD, Sheinin O, Gozal Y. Use of ultrasound guidance in the insertion of radial artery catheters. Crit Care Med. 2003;31:481–4
23. Ueda K, Bayman EO, Johnson C, Odum NJ, Lee JJ. A randomised controlled trial of radial artery cannulation guided by doppler vs palpation vs ultrasound. Anaesthesia. 2015;70:1039–44
24. Kiberenge RK, Ueda K, Rosauer B. Ultrasound-guided dynamic needle tip positioning technique versus palpation technique for radial arterial cannulation in adult surgical patients: a randomized con trolled trial. Anesth Analg. 2018;126:120–6
25. Hansen MA, Juhl-Olsen P, Thorn S, Frederiksen CA, Sloth E. Ultrasonography-guided radial artery catheterization is superior compared with the traditional palpation technique: a prospective, randomized, blinded, crossover study. Acta Anaesthesiol Scand. 2014; 58: 446–52
26. Genre Grandpierre R, Bobbia X, Muller L, Markarian T, Occe´an B-V, Pommet S et al. Ultrasound guidance in difficult radial artery puncture for blood gas analysis: A prospective, randomized controlled trial. Andò G, editor. PLoS One. 2019;14: e0213683
27. Abdalla UE, Elmaadawey A, Kandeel A. Oblique approach for ultrasound guided radial artery catheterization vs transverse and longitudinal approaches, a randomized trial. J Clin Anesth. 2017;36:98–101
28. Song IK, Choi JY, Lee JH, Kim EH, Kim HJ, Kim HS, et al. Short-axis/out-ofplane or long-axis/in-plane ultrasound-guided arterial cannulation in children: a randomised controlled trial. Eur J Anaesthesiol. 2016;33: 522–7.
29. Nakayama Y, Nakajima Y, Sessler DI, Ishii S, Shibasaki M, Ogawa S, et al. A novel method for ultrasound-guided radial arterial catheterization in pediatric patients. Anesth Analg. 2014;118:1019–26
30. Goldstein A, Madrazo BL. Slice-thickness artifacts in gray-scale ultrasound. J Clin Ultrasound. 1981;9:365–75.
31. Gao YB, Yan JH, Gao FQ, Pan L, Wang XZ, Lv CJ. Effects of ultrasound guided radial artery catheterization: an updated meta-analysis. Am J Emerg Med. 2015;33:50–5.

32. Pacha HM, Alahdab F, Al-Khadra Y, Idris A, Rabbat F, Darmoch F, et al. Ultrasound-guided versus palpation-guided radial artery catheterization in adult population: a systematic review and meta-analysis of randomized controlled trials. Am Heart J. 2018;204:1–8.
33. Bhattacharjee S, Maitra S, Baidya DK. Comparison between ultrasound guided technique and digital palpation technique for radial artery cannulation in adult patients: an updated meta-analysis of randomized controlled trials. J Clin Anesth. 2018;47:54–9.
34. Berk D, Gurkan Y, Kus A, Ulugol H, Solak M, Toker K. Ultrasound-guided radial arterial cannulation: long axis/in-plane versus short axis/out-of-plane approaches? Journal of clinical monitoring and computing 2013;27(3): 319-24.
35. Tian Y, Bai B, Zhang Y, Che L, Wang J, Wang Y, et al. The improved catheterization is associated with the deeper radial arteries in ultrasound-guided dynamic needle tip positioning technique. Front. Med. 2022;9:803124
36. 36. Nakayama Y, Nakajima Y, Sessler DI, Ishii S, Shibasaki M, Ogawa S, et al. A novel method for ultrasound-guided radial arterial catheterization in pediatric patients. Anesth Analg. 2014;118:1019–26.