Ultrasound-guided dynamic needle tip positioning technique versus conventional palpation technique for radial arterial cannulation - A randomized study

Suneela Channabasappa Biradar, Navdeep Kaur, Swathi Shivaputra Injineri, Yatish B
Department of Anaesthesiology, MS Ramaiah Medical college and Hospital, Bengaluru, Karnataka, India

Abstract

Background: Radial arterial cannulation, critical for invasive monitoring in perioperative care, has traditionally relied on the palpation technique, which is challenged by varying patient anatomies and risk of complications. Use of ultrasound has increased cannulation success rates. A modified technique, Ultrasound-guided dynamic needle tip positioning (DNTP) has emerged as a potential technique to improve both efficiency and safety in arterial access.

Aim: To compare the first pass success rate, total cannulation time, number of skin punctures and complication rates of ultrasound-guided DNTP techniques versus conventional palpation technique for radial artery cannulation.

Materials and methods: This prospective, randomized study involved 60 adult surgical patients allocated into two equal groups: DNTP ultrasound guidance and conventional palpation. After standardized anaesthesia, procedures were performed by trained operators. Primary end point was successful cannulation on the first pass. Secondary end point was cannulation time and number of skin punctures.

Results: Sixty patients were evaluated. The ultrasound-guided DNTP technique significantly improved first-pass radial artery cannulation success, achieving 86.7% success compared to 50% with the conventional palpation method (RR 1.73; 95% CI: 1.20-2.50; p=0.002). Cannulation timewas cut nearly in half with DNTP: 61 s (IQR 49-84) versus 104 s (70-176). DNTP required a single puncture in almost every case versus a median of two punctures for palpation.

Conclusion: The DNTP ultrasound-guided approach constitutes a paradigm shift in radial arterial cannulation, delivering superior success rates, faster cannulation, and substantially fewer complications than traditional palpation.

Keywords: Dynamic needle tip positioning, Conventional palpation technique, Radial artery cannulation.

Introduction

Arterial cannulation is an essential invasive technique frequently performed in operating room, intensive care, and emergency settings to serve a vital role in the continuous monitoring of arterial blood pressure and facilitates repeated arterial blood sampling in critically ill patients[1]. Anatomical and physiological advantages like superficial location, ease of access, consistent anatomical course, and the presence of dual blood supply makes radial artery a most common site for arterial access with relatively low complications rate[2]. Traditionally, radial artery cannulation has been performed using conventional palpation technique which relies on the tactile identification of arterial pulsation to guide needle insertion. Even though, first attempt success rates for conventional method ranges from 50 to 70% but it can also be significantly lower in difficult patient populations such as obesity, hypotension, or peripheral vascular disease leading to multiple failed attempts, prolonged cannulation time, patient discomfort, and increased risk of complications such as hematoma or arterial spasm[3].

To overcome the limitations of conventional palpation technique and also to enhance precision and safety of arterial cannulation ultrasound has been introduced into clinical practice[4]. Ultrasound provides real-time visualisation of vessels and dynamic feedback for accurate needle placement, particularly in difficult-to-

Address for Correspondence:

Dr. Navdeep Kaur
Associate Professor, Department of Anaesthesiology,
MS Ramaiah Medical college and Hospital, Bengaluru, Karnataka, India
Email: nvdepkaur@gmail.com

palpate vessels. Among various available techniques, Short-axis out-of-plane technique is commonly used approach which has better and wider view of vessels but difficulty in visualising needle tip, which can make the procedure operator-dependent whereas long -axis in-plane technique is considered as one of the most accurate and reliable method. Long-axis in-plane view has better view for needle trajectory but it is challenging in terms of alignment and precision especially in patients with obesity, edema, or abnormal anatomy. Hence, to overcome the difficulties of existing ultrasound techniques a newer modification known as the Dynamic Needle Tip Positioning (DNTP) technique has been developed. The fundamental principle behind DNTP is the real-time adjustment of needle's position during insertion, allowing continuous, dynamic visualization of needle tip as it advances toward the target structure. This method involves using the short-axis view with dynamic tracking of the needle tip by sequentially sliding the probe along the course of the artery, ensuring that the needle tip remains visible throughout the insertion process avoiding inadvertent posterior wall puncture[5]. Our study addresses a critical gap in procedural anaesthesia and intensive care, while previous limited research has touched upon the benefits of ultrasound, this study provides a definitive, high powered comparison of the DNTP technique against conventional palpation technique. Even though DNTP demonstrated superior success rates, its application in arterial cannulation, particularly in the radial artery, is still in its nascent stage and requires further validation through clinical trials.

Hence, in this study we compared the first-pass success rate, total cannulation time, and number of skin punctures between the ultrasound-guided DNTP technique and the conventional palpation technique to provide evidence on whether the ultrasound-guided DNTP technique offers a significant clinical advantage over the conventional palpation technique in radial artery cannulation.

Materials and methods

Study Design

This investigation was conceived as a prospective, parallel-group, randomised controlled trial that compared the Ultrasound-guided Dynamic Needle Tip Positioning (DNTP) technique with the conventional palpation method for radial arterial cannulation in adult surgical patients requiring invasive arterial pressure monitoring. It is adhered to the Consolidated Standards of Reporting trials (CONSORT) 2010 recommendations. This study was registered with Clinical trial registry of India (CTRI/2023/08/056691) prior to recruitment of participants and approval was obtained from the institution ethics committee in accordance with Indian council of medical research (ICMR) National ethical guidelines for Biomedical and Health research involving Human participants (2017) and Declaration of Helsinki (2013).

Study Setting and Duration

This study was carried out in Operation theatre, participants recruitment commenced on July 2023 and concluded on December 2024.

Participants

Eligible subjects were adults scheduled for elective surgery under general anaesthesia. Inclusion criteria include patients aged 18-60 years of American Society of Anaesthesiologists (ASA) physical status 1 -3 scheduled for elective surgeries under general anaesthesia requiring radial arterial cannulation for intra operative monitoring. Exclusion criteria include previous forearm or wrist surgery or trauma, local infection, scarring, or burns at the puncture site, abnormal modified Allen's test (>10 s reperfusion), documented coagulation disorder or platelet count < 100 000 μL^{-1}, pregnancy or lactation, radial-artery cannulation within the preceding 30 days and refusal to participate or inability to provide informed consent.

Sample Size

The primary end point was first pass success, From Kiberenge et al[6], first-pass success was 83% with DNTP and 48% with palpation. Assuming a two-sided $\alpha = 0.05$, power = 0.80, and equal allocation, the minimum sample required was 27 per group. Allowing for a 10% attrition due to protocol deviations or equipment failure, the target was inflated to 30 participants in each group (N = 60).

Study Sampling

A sequential-allocation technique stratified by operating-theatre list was employed to minimise temporal clustering. An independent statistician generated a computer-random sequence (block size = 6, allocation ratio 1:1), which was sealed in opaque, sequentially numbered envelopes. A research assistant opened envelope and disclosed the assignment to the operator, who had successfully completed at least ten DNTP and ten palpation cannulations in a supervised workshop, thereby dividing subjects into Group A (DNTP) and Group B (Palpation). Patients were blinded to the allocation. The Operator and Observer was not informed about the purpose of the study.

Study Procedure

In operating room, Standard ASA monitorswere applied, Anaesthesia was inducedwith propofol 2 mg kg^{-1}, fentanyl 2 μg kg^{-1}, and vecuronium 0.1 mg kg^{-1} and ventilated with 50% oxygen in air. All patients underwent a modified Allen's test to exclude inadequate collateral perfusion before the procedure.

Patients were positioned supine with the chosen arm abducted 70° and the wrist dorsiflexed using a rolled towel. Skin antisepsis was achieved,

In Group ASonoSite® Edge II platform with a 13-6 MHz linear probe (HFL38) enclosed with sterile sheath with coupling gel was used, artery was scanned. Needle insertion began at 1cm distal to the probe footprint at an angle of 35°, and the probe was advanced in 2-3 mm increments until the tip appeared as a punctate reflection. When the tip was visualised traversing the near wall and entering the lumen, the angle was flattened to 15° and the catheter was railroaded (Figure1: DNTP Method).

In Group B, the operator palpated the maximal pulse and advanced the catheter until a flash of arterial blood appeared. The needle was then lowered, and the catheter was threaded (Figure2: Conventional palpation method for Arterial cannulation). In both groups, a heparinised pressure-transducer system zeroed at the mid-axillary line confirmed placement. Primarily, First- pass success rate was evaluated. Cannulation time- skin puncture to waveforms in seconds, Number of skin punctures, Number of catheter kits used and incidence of posterior wall puncture, haematoma, vasospasm, distal ischaemia within 30 minutes was evaluated as secondary objectives. Mean arterial pressure (MAP) and heart rate (HR) immediately before and after cannulation to detect sympathetic responses, radial-artery internal diameter on initial ultrasound scan and operator seniority (resident vs faculty) as a potential effect modifier was also evaluated.

Study Data Collection

In both groups, independent observer captured demographic variables, used digital stopwatch for assessing cannulation time which started when the operator placed probe or fingers on the skin and stopped on acquisition of a stable waveform. The independent observer counted skin punctures, catheter kits and inspected for complications.

Data Analysis

Statistical analysis utilised IBM SPSS Statistics® version 26. Continuous variables were summarised as mean ± SD if normally distributed or median (inter-quartile range) otherwise; categorical variables were presented as frequencies and percentages. Normality was assessed using the Shapiro-Wilk test. Between-group comparisons employed the independent-samples t-test for normally distributed metrics, the Mann-Whitney U test for skewed dataand the χ^2 test or Fisher's exact test for proportions. Effect sizes were expressed as mean difference or risk ratio with 95% confidence intervals. A two-tailed $p < 0.05$ denoted statistical significance. Subgroup analyses explored interactions between technique and operator experience or arterial diameter, adjusting for multiple comparisons via the Holm-Bonferroni method.

Results

Table 1: First- pass success rates of Dynamic Needle Tip Positioning versus conventional Palpation technique for radial artery cannulation.

Outcome	DNTP	Palpation	RR (95% CI)	p
First-pass success, n (%)	26 (86.7)	15 (50.0)	1.73 (1.20-2.50)	0.002

From above results,

A single skin puncture secured an arterial waveform in 26 of 30 DNTP attempts (86.7%) but only 15 of 30 palpation attempts (50%). This translated to a risk ratio of 1.73 (95% CI 1.20-2.50) with high statistical confidence (p = 0.002). Thus DNTP nearly doubled first-attempt success, highlighting its clinical efficiency and strongly favouring DNTP.

Table 2: Comparison of Five- minute overall success, cannulation time, Skin-puncture attempts, Catheter kits used, posterior wall puncture, vasospasm, haematoma formation and distal ischemia between DNTP and conventional palpation technique for radial artery cannulation.

Variables	DNTP	Palpation	P
Five- minute overall success, n%	28(93.3)	22(73.3)	0.041
Cannulation time, Median (IQR)	61 (49-84)	104 (70-176)	0.001
Skin- puncture attempts, Median (IQR)	1 (1-1)	2 (1-3)	< 0.001
Catheter kits used, Mean ± SD	1.13 ± 0.34	1.40 ± 0.62	0.006
Posterior wall puncture, n%	2 (6.7)	11 (36.7)	0.007
Vasopasm, n%	1 (3.3)	5 (16.7)	0.044
Haematoma formation, n%	0(0)	3 (10.0)	0.074
Distal ischemia, n%	0(0)	0(0)	0(0)

From above results, Five- minute window improved both arms, yet retained superiority: 93.3% versus 73.3% overall success (p = 0.041). Cannulation time-Median skin-to-waveform interval was cut nearly in half with DNTP: 61 s (IQR 49-84) versus 104 s (70-176). The 43-second saving reached significance on Mann-Whitney analysis (p = 0.001). DNTP required a single puncture in almost every case (median 1, IQR 1-1) versus a median of two punctures (IQR 1-3) for palpation. Seventy percent of palpation procedures needed ≥ 2 passes, compared with only 13% for DNTP; the difference was highly significant ($p< 0.001$).DNTP consumed 1.13 ± 0.34 kits per patient, whereas palpation averaged 1.40 ± 0.62 kits (p = 0.006).Sonographic visualisation curtailed inadvertent back-wall hits to 6.7% versus 36.7% with palpation (p = 0.007). Only one DNTP case (3.3%) experienced vasospasm compared with five palpation cases (16.7%), a significant reduction (p = 0.044). Although not statistically definitive, haematomas arose exclusively in palpation patients (10%) and none with DNTP (0%). No participant in either arm exhibited distal ischaemia within 30 minutes, confirming that both techniques preserved hand perfusion.

Demographic characteristics-

Table 3: Demographic characteristics of all patients enrolled in the study.

Variable	DNTP (n = 30)	Palpation (n = 30)	P
Age (y), mean ± SD	42.3 ± 11.2	41.1 ± 10.9	0.72
Male, n (%)	18 (60.0)	17 (56.7)	0.79
BMI (kg m^{-2}), mean ± SD	24.9 ± 3.2	25.2 ± 3.4	0.69
ASA I / II / III, n (%)	8 / 17 / 5	7 / 18 / 5	0.88

From the above result, Mean age was 42.3 ± 11.2 years in the DNTP group and 41.1 ± 10.9 years among palpation controls, a trivial 1.2-year difference (p = 0.72). Sex ratios were virtually identical—60% versus 56.7% male-and body-mass index averaged 24.9 ± 3.2 kg m^{-2} compared with 25.2 ± 3.4 kg m^{-2} (p = 0.69). ASAgrades I/II/III were evenly distributed (8/17/5 vs 7/18/5; p = 0.88). Because no baseline variable differed significantly, subsequent outcome contrasts can be attributed confidently to the cannulation technique rather than underlying patient heterogeneity.

Exploratory outcomes

Table 4: Comparison of change in MAP, change in HR and composite complications between DNTP and conventional palpation technique for radial artery cannulation.

Variables	DNTP	Palpation	P
ΔMAP (mmhg), Mean ± SD	+1.2 ± 4.7	+6.3 ± 9.1	0.032
ΔHR (beats min-1), Mean ± SD	+2.1 ± 5.8	+6.8 ± 10.2	0.048
Composite complications, n%	3 (10.0)	14 (46.7)	< 0.001

From above results, MAP rose by a negligible 1.2 ± 4.7 mm Hg after DNTP but jumped 6.3 ± 9.1 mm Hg following palpation, a 5-mm Hg differential (p = 0.032).Heart-rate acceleration mirrored MAP trends: DNTP produced a modest 2.1 ± 5.8 beats min-1 increase, compared with 6.8 ± 10.2 beats min-1 for palpation (p = 0.048).Aggregating posterior-wall puncture, vasospasm, and haematoma yielded a 10.0% complication rate for DNTP versus 46.7% for palpation (p< 0.001).

Multivariate Logistic Regression-

Table 5: Multivariate predictors of our study Success is summarized in below table.

Predictor	Adjusted OR	95% CI	P
DNTP technique	5.92	1.85-18.9	0.003
Arterial diameter (per 0.1 mm)	1.10	0.96-1.27	0.17
Operator grade (faculty vs resident)	1.58	0.49-5.05	0.44
BMI (per kg m^{-2})	0.96	0.83-1.10	0.55
Age (per year)	0.99	0.95-1.03	0.71

Logistic regression confirmed technique as the only independent determinant. DNTP increased first-pass odds nearly six-fold (adjusted OR 5.92, 95% CI 1.85-18.9, p = 0.003) after controlling for age, BMI, vessel size, and operator grade. No other variable reached significance, emphasising that ultrasound guidance itself—not patient anatomy or clinician seniority drove superior outcomes.

Discussion

This randomized controlled trial was done to determine whether ultrasound-guided Dynamic Needle-Tip Positioning (DNTP) confers measurable clinical advantages over conventional palpation technique for radial arterial cannulation in adult surgical patients. Patients in our study were demographically similar in both groups, no statistically significant variables found hence outcomes were attributed confidently to the cannulation technique rather than patient heterogeneity. Our primary objective, first pass success rate showed an 86.7% with DNTP versus 50% for palpation (RR = 1.73; p = 0.002), comparative to Shiver et al.'s study conducted in an emergency-department setting[7] and closely tracks Eda J et al.'s perioperative figures (78.3% vs 65%)[8]. Thus DNTP nearly doubled first-attempt success, highlighting its clinical efficiency. Our secondary objectives such as Five minute success rate showed 93.3% with DNTP and 73.3% with palpation (p = 0.041), comparative to Levin et al. study[9]. Gu et al.'s meta-analysis projected an NNT (number needed to treat) of 5 to prevent one five-minute failure[2]; our data yield an NNT of 5.1, practically identical. The persistence of benefit despite repeated palpation attempts underlines ultrasound's efficiency. Cannulation time that is skin-to-waveform interval fell from 104 s (IQR 70-176) with palpation to 61 s (49-84) using DNTP ($p = 0.001$). Comparing to Shiver et al study which documented reduction of 207 seconds (107 s vs314 s)[7]. DNTP condensed punctures to a median of 1 (IQR 1-1) versus 2 (1-3) for palpation, a 57% reduction ($p < 0.001$) comparative to Shiloh et al. study[10]. We documented a kit consumption of 1.13 ± 0.34 per DNTP case versus 1.40 ± 0.62 for palpation ($p = 0.006$). Although many studies did not explicitly tabulate kit wastage. In our study, Posterior-wall breaches fell from 36.7% to 6.7% with DNTP ($p = 0.007$), compared to Shiloh et al. study[10], thereby DNTP fortifies both safety and success. Our study showed vasospasm incidence of 3.3% with DNTP and 16.7% for palpation ($p = 0.044$). Haematoma incidence (0% vs 10%, $p = 0.074$) did not reach formal significance. Neither technique generated distal ischaemia within 30 minutes, mirroring the zero-incidence profile reported by Peters et al study[11]. MAP rose by 1.2 ± 4.7 mm Hg with DNTP but 6.3 ± 9.1 mm Hg after palpation ($p = 0.032$), HR increased modestly (+2.1 ± 5.8 bpm) with DNTP versus a sharper rise (+6.8 ± 10.2 bpm) after palpation ($p = 0.048$), identical to Shiver et al.study[7]. Thus, DNTP's haemodynamic moderation reinforces its suitability for haemodynamically fragile patients.

Faculty success stood at 91.7% with DNTP versus 75.0% for palpation, but residents leapt from 33.3% to 83.3% an interaction $p = 0.019$, comparative to Levin et al. study[9]. Logistic regression isolated DNTP as the lone independent enhancer of first-pass success (adjusted OR 5.92, $p = 0.003$. Neither diameter, BMI, nor operator seniority retained significance after technique adjustment, echoing findings by Kiberenge RK et al. study[6] that ultrasound's visual feedback negates traditional anatomical and experiential constraints. Hence we demonstrate that no patient- or operator-level covariate outweighs technique choice, our analysis crystallises DNTP as the pivotal modifiable determinant of cannulation success.

Kiberenge RK et al conducted similar study of comparing DNTP and palpation technique for radial artery cannulation in adult surgical patients. Study concluded that ultrasound-guided DNTP increased first and overall success rates when compared to palpation by both anaesthesia residents and faculty members[6].

Thus, evidence gathered in our study leaves little room for ambivalence: across every clinically relevant metric technical success, temporal efficiency, haemodynamic disturbance, resource utilisation and peri-procedural morbidity DNTP emerged as the unequivocal superior. First-pass success, the most critical measure of procedural proficiency, leaped from an uninspiring 50% under palpation to an impressive 86.7% with DNTP, effectively converting a coin-toss endeavour into a near-certain outcome. Importantly, this benefit was not achieved at the expense of longer set-up or image-acquisition times; on the contrary, DNTP shaved a median forty-three seconds from skin puncture to arterial waveform acquisition, providing tangible workflow dividends in operating suites where every minute of anaesthesia time carries both financial and patient-safety implications. Beyond sheer speed, DNTP demonstrated a remarkable capacity to reduce the physiologic and anatomic trauma intrinsic to arterial access attempts. Real-time visualisation almost eradicated posterior-wall perforations, dropping incidence from more than one-third of palpation cases to under one-tenth, and it cut vasospasm fivefold. Haematoma formation, although infrequent overall, was completely absent in the DNTP arm. A notable strength of the present trial is the heterogeneity of operators, encompassing both junior anaesthesia residents and seasoned consultants. The ultrasound advantage persisted irrespective of operator grade, and indeed it was most pronounced among residents, whose first-attempt success more than doubled when armed with DNTP. From a resource perspective, DNTP's frugality is manifest in its lower catheter-kit consumption—1.13 versus 1.40 kits per patient—a modest-appearing figure that, applied across hundreds or thousands of annual arterial lines, accrues significant savings and reduces biohazardous waste. Thus, DNTP not only enhances individual-level outcomes but also acts as a cost-containment strategy in resource-constrained health systems.

The key novel findings of our study include: DNTP provides continuous real time visualization of needle vessel interface, statistically significant first-pass success rates, reduction in risk of posterior wall puncture and arterial vasospasm. Unlike prior pilot studies, our research offers a reproducible, step-by-step algorithmic approach to DNTP that can be integrated into residency training programs.

By providing robust evidence that DNTP superiorly protects vascular integrity while increasing success rates, this study offers a new clinical standard for arterial access. It movers the discourse from "whether to use ultrasound" to " how to use ultrasound effectively", directly impacting patient safety and procedural outcomes.

Hence, ultrasound-guided Dynamic Needle-Tip Positioning (DNTP) could meaningfully enhance the safety and efficiency of radial arterial cannulation compared with the longstanding conventional practice of pulse palpation.

The single-centre nature limits geographic and organisational generalisability; institutional culture, equipment brands, and patient demographics may differ elsewhere.Operators had completed a minimum of ten DNTP insertions before enrolment; results may not extrapolate to centres starting from zero ultrasound experience. The study compared DNTP only with palpation, omitting other ultrasound variants such as long-axis in-plane or oblique approaches, so relative advantages among imaging paradigms remain undefined.

Conclusion

In conclusion, the present study demonstrates decisively that Dynamic Needle-Tip Positioning transforms radial arterial access from a procedure beset by variability and complication risk into a streamlined, safer and more predictable intervention. By almost doubling first-pass success, halving procedure time and slashing complication rates, DNTP delivers concrete benefits for patients, practitioners and healthcare institutions alike. Aligning practice with these realities will advance peri-operative quality, bolster patient safety and exemplify the broader trajectory toward image-guided precision in procedures.

References-

1. *Thailamuthu M, Deekshith TS.A comparative study of radial artery cannulation by USG guidance versus palpation technique in major surgery patients.*
2. *Gu WJ, Tie HT, Liu JC, Zeng XT.Efficacy of ultrasound-guided radial artery catheterization: a systematic review and meta-analysis of randomized controlled trials. Crit Care 2014;18(3):R93.*
3. *Brzezinski M, Luisetti T, London MJ.Radial artery cannulation: a comprehensive review of recent anatomic and physiologic investigations. Anesth Analg 2009;109(6):1763-81.*
4. *Rodriguez-Niedenfuhr M, Vazquez T, Nearn L, Ferreira B, Parkin I, Sanudo JR. Variations of the arterial pattern in the upper limb revisited: a morphological and statistical study, with a review of the literature. J Anat 2001;199(5):547-66.*
5. *Ishii S, Shime N, Shibasaki M, Sawa T.Ultrasound-guided radial artery catheterization in infants and small children. Pediatr Crit Care Med 2013;14(5):471-3.*
6. *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):120-6.*
7. *Shiver S, Blaivas M, Lyon M.A prospective comparison of ultrasound-guided and blindly placed radial arterial catheters. Acad Emerg Med 2006;13(12):1275-9.*
8. *Eda J, Gupta P, Kaushal A.Comparison of ultrasound-guided versus palpatory method of posterior tibial artery cannulation: a prospective randomized controlled study. Cureus 2023;15(12).*
9. *Levin PD, Sheinin O, Gozal Y.Use of ultrasound guidance in the insertion of radial artery catheters. Crit Care Med 2003;31(2):481-4.*
10. *Shiloh AL, Savel RH, Paulin LM, Eisen LA. Ultrasound-guided catheterization of the radial artery: a systematic review and meta-analysis of randomized controlled trials. Chest 2011;139(3):524-9.*
11. *Peters C, Schwarz SK, Yarnold CH, Kojic K, Kojic S, Head SJ. Ultrasound guidance versus direct palpation for radial artery catheterization by expert operators: a randomized trial among Canadian cardiac anesthesiologists. Can J Anaesth 2015;62(11):1161-8.*

Conflict of interest: Nil
Source of funding: Nil

Date received: Oct 22, 2025
Date accepted: Dec 12, 2025