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A Comparative Study of the Ease of Radial Artery Cannulation Using the Palpation Method in Patients Undergoing Surgery Under General Anaesthesia

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Abstract:
Background: Radial artery cannulation is a common procedure in patients undergoing surgery requiring continuous hemodynamic monitoring. While the palpation method is widely practiced, its success may be influenced by patient-specific factors such as body habitus and pulse quality. This study aimed to evaluate the ease and success of radial artery cannulation using the palpation method and identify predictors of cannulation difficulty in adult surgical patients under general anaesthesia.
Methods: This prospective observational study was conducted on 92 adult patients undergoing elective surgery under general anaesthesia. Radial artery cannulation was performed using the palpation method by experienced anaesthesiologists. Data were collected on demographic variables, BMI, ASA class, pulse strength, number of attempts, time to successful cannulation, ease of cannulation, and complications. Subgroup analyses were conducted based on BMI and pulse strength. Binary logistic regression was used to identify independent predictors of difficult cannulation.
Results: First-attempt success was achieved in 68.5% of patients, with an overall success rate of 96.7%. The mean number of attempts was 1.45 ± 0.69, and the mean cannulation time was 62.4 ± 18.9 seconds. Difficult cannulation occurred in 15.2% of patients. Obese patients (BMI ≥30 kg/m²) had lower first-attempt success (42.9%) and higher rates of difficulty (35.7%; $p = 0.009$) compared to those with BMI <25 kg/m². Similarly, patients with weak radial pulse had significantly lower first-pass success (42.9%) and higher difficulty (42.9%; $p < 0.001$). Logistic regression identified BMI ≥30 kg/m² (AOR: 4.82, $p = 0.020$) and weak pulse (AOR: 7.26, $p = 0.001$) as independent predictors of difficult cannulation. Complications were observed in 9.8% of cases.
Conclusion: The palpation method remains a viable technique for radial artery cannulation, with high overall success in skilled hands. However, obesity and weak radial pulse are significant predictors of cannulation difficulty. Early identification of such factors should prompt consideration of ultrasound guidance to improve outcomes and reduce complications

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Introduction

Radial artery cannulation is an essential procedure in anaesthesia and critical care, frequently used for invasive arterial blood pressure monitoring and serial arterial blood gas analysis. Among various arterial access sites, the radial artery is preferred due to its superficial anatomical location, ease of palpation, low complication rate, and the presence of dual blood supply to the hand through the ulnar artery [1]. In the perioperative setting, especially during surgeries performed under general anaesthesia, timely and successful arterial cannulation is vital for hemodynamic monitoring, particularly in patients with significant comorbidities or anticipated haemodynamic fluctuations [1].

The palpation technique—where the artery is located by tactile identification of the pulse and cannulated using anatomical landmarks—remains the most commonly employed method worldwide, especially in low- and middle-income countries (LMICs) where ultrasound guidance may not be readily available due to resource constraints [2]. Studies have shown that the first-attempt success rate of radial artery cannulation using the palpation method ranges between 50% and 76%, with overall success after multiple attempts ranging from 85% to 95% depending on operator experience [3,4]. However, the method is associated with a higher number of attempts and longer cannulation time compared to ultrasound-guided techniques [5].

Under general anaesthesia, radial artery cannulation via palpation presents additional challenges. Anaesthetic-induced vasodilation, hypotension, and reduction in arterial tone can obscure the palpability of the pulse, particularly in patients with obesity, hypotension, or peripheral vascular disease [6]. Repeated failed attempts can increase patient discomfort (postoperatively), risk of hematoma, arterial spasm, and procedural delays, especially in high-stakes surgical settings [7].

Although several studies have compared the palpation technique with ultrasound-guided methods, there is a paucity of data specifically focusing on the effectiveness and ease of radial artery cannulation using palpation alone in anaesthetized patients [8]. Furthermore, limited literature is available that stratifies success rates by demographic factors such as age, BMI, and comorbidities within the context of general anaesthesia. Considering that ultrasound machines are not universally available in all operating theatres in India and other LMICs, it becomes clinically relevant to evaluate how effectively the palpation technique performs in routine surgical settings [8].

This study aims to assess and compare the ease of radial artery cannulation using the palpation method in adult patients undergoing elective surgery under general anaesthesia, with particular emphasis on first-attempt success rate, time taken for cannulation, number of attempts, and associated complications. By identifying demographic or clinical variables that affect cannulation ease, this study may inform strategies for patient selection, training of anaesthesia providers, and optimal allocation of advanced imaging resources.

Material and methods

Study Design and Setting

This prospective, observational study was conducted in the Department of Anaesthesiology at a tertiary care teaching hospital located in North India. The study period spanned 24 months, from June 2023 to June 2025. Prior to initiation, ethical clearance was obtained from the Institutional Ethics Committee, and written informed consent was obtained from all participants.

Study Population

The study included adult patients aged between 18 and 65 years scheduled to undergo elective surgical procedures under general anaesthesia that required intra-arterial blood pressure monitoring. Only patients with a palpable radial artery and classified as American Society of Anesthesiologists (ASA) physical status I or II were included. Patients were excluded if they had conditions that could interfere with radial artery cannulation, such as peripheral vascular disease, local infection or scarring at the cannulation site, previous cannulation at the same site, a positive Allen's test indicating inadequate ulnar collateral circulation, Raynaud's disease, morbid obesity (BMI > 40 kg/m^2), hypotension (MAP < 60 mmHg), or coagulation abnormalities (platelet count < 100,000/mm^3 or INR > 1.5).

Sample Size and Sampling Method

Sample size was calculated based on a previously reported study by Grocott e al., first-attempt success rate of 65% for radial artery cannulation using the palpation method [9]. To detect a minimum

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clinically significant difference of 15% in success rates between patient subgroups (such as BMI categories), with a confidence level of 95% and power of 80%, the required sample size was 92 patients.

Preoperative Anaesthetic Protocol

All enrolled patients underwent standard preoperative assessment including history, physical examination, and laboratory investigations. In the operating room, routine monitoring (non-invasive blood pressure, ECG, pulse oximetry) was instituted. After pre-oxygenation, general anaesthesia was induced using intravenous propofol (2–2.5 mg/kg), fentanyl (2 µg/kg), and vecuronium (0.1 mg/kg) to facilitate endotracheal intubation. Anaesthesia was maintained with a mixture of oxygen, nitrous oxide, and isoflurane (0.8–1.2 MAC), titrated to clinical requirements. Radial artery cannulation was performed after induction, once haemodynamic stability and adequate anaesthetic depth were ensured.

Radial Artery Cannulation Procedure

Cannulation was performed on the non-dominant wrist unless contraindicated. The wrist was extended to approximately 30 degrees using a rolled towel. Aseptic precautions were ensured using 2% chlorhexidine in alcohol and sterile drapes. The radial artery was located by palpation just proximal to the styloid process of the radius. A 20-gauge over-the-needle arterial cannula was inserted at a 30–45° angle to the skin using the direct technique. Upon obtaining arterial backflow, the catheter was advanced into the lumen and secured after confirming the presence of a characteristic arterial waveform on the pressure transducer. All procedures were performed by anaesthesiologists with a minimum of three years of post-MD experience to ensure technical consistency and minimize operator-dependent variability.

Data Collection and Outcome Measures

The primary outcome was the first-attempt success rate, defined as successful cannulation on the first skin puncture with waveform confirmation. Secondary outcomes included total number of attempts (each skin puncture counted as one attempt), time required for successful cannulation (measured in seconds from skin puncture to waveform confirmation), and the operator's subjective assessment of ease of cannulation (classified as "easy," "moderate," or "difficult"). Complications such as hematoma, arterial spasm, or cannulation failure (defined as more than three unsuccessful attempts) were recorded. In cases of failure, conversion to ultrasound-guided cannulation was noted. Additional data collected included demographic variables (age, sex), clinical parameters (BMI, ASA grade, comorbidities such as diabetes or hypertension), and intraoperative haemodynamic values (systolic BP at time of cannulation).

Statistical Analysis

All collected data were entered into Microsoft Excel and analysed using IBM SPSS Statistics Version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation (SD) and compared using the ANOVA, independent samples t-test or Mann–Whitney U test based on normality of distribution. Categorical variables were expressed as frequencies and percentages and compared using the Chi-square test or Fisher's exact test as applicable. Binary Logistic Regression Analysis of Predictors of Difficult Radial Artery Cannulation was also calculated. A p-value < 0.05 was considered statistically significant.

Results

A total of 92 patients were included in the study, with a mean age of 45.6 ± 12.3 years. The majority were male (59.8%) and had a mean BMI of 26.1 ± 3.4 kg/m². Most patients fell into the 25–29.9 kg/m² BMI category (47.8%), followed by <25 kg/m² (37.0%) and ≥30 kg/m² (15.2%). ASA physical status was nearly evenly distributed between Class I (52.2%) and II (47.8%). The dominant hand was right-sided in 91.3% of patients, and in 87.0% of cases, radial artery cannulation was performed on the non-dominant (left) hand. Comorbidities included diabetes in 23.9% and hypertension in 29.3% of participants. The mean baseline systolic blood pressure was 122.6 ± 14.8 mmHg. On palpation, the radial pulse was subjectively assessed as strong in 77.2% of patients and weak in 22.8% (Table 1)

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Table 1: Baseline Demographic and Clinical Characteristics of Study Participants (n = 92).

Variables	Frequency (%) / Mean ± SD
Age (in years)	45.6 ± 12.3
Gender	
— Male	55 (59.8%)
— Female	37 (40.2%)
BMI (kg/m²)	26.1 ± 3.4
BMI (kg/m²) Category	
— <25	34 (37.0%)
— 25 – 29.9	44 (47.8%)
— ⩾30	14 (15.2%)
ASA physical status	
— I	48 (52.2%)
— II	44 (47.8%)
Dominant Hand	
— Right	84 (91.3%)
— Left	8 (8.7%)
Cannulated Hand (non-dominant)	
— Right	12 (13.0%)
— Left	80 (87.0%)
Comorbidities	
— Diabetes	22 (23.9%)
— Hypertension	27 (29.3%)
Baseline systolic BP (mmHg)	122.6 ± 14.8
Pulse strength (subjective)	
— Strong	71 (77.2%)
— Weak	21 (22.8%)

BMI classified per WHO Asia-Pacific guidelines. ASA = American Society of Anesthesiologists. BP = Blood Pressure.

Radial artery cannulation using the palpation method was successful on the first attempt in 63 patients (68.5%), while overall success within three attempts was achieved in 89 cases (96.7%). The mean number of attempts was 1.45 ± 0.69, and the average time to successful cannulation was 62.4 ± 18.9 seconds. In terms of procedural ease, cannulation was rated as easy in 52 patients (56.5%), moderate in 26 (28.3%), and difficult in 14 (15.2%). Complications were observed in 9 patients (9.8%), with hematoma being the most common (4.3%), followed by arterial spasm (2.2%), bruising (2.2%), and failed cannulation in 3 cases (3.3%) which required conversion to ultrasound-guided technique (Table 2).

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Table 2: Primary and Secondary Outcomes of Radial Artery Cannulation Using Palpation Method (n = 92).

Variables	Frequency (%) / Mean ± SD
First-attempt success	63 (68.5%)
Overall success (⩽3 attempts)	89 (96.7%)
Failed cannulation (⩾4 attempts)	3 (3.3%)
Number of attempts	1.45 ± 0.69
Time to successful cannulation (seconds)	62.4 ± 18.9
Ease of cannulation	
— Easy	52 (56.5%)
— Moderate	26 (28.3%)
— Difficult	14 (15.2%)
Complications observed	9 (9.8%)
Type of Complications	
— Hematoma	4 (4.3%)
— Arterial spasm	2 (2.2%)
— Bruising/ecchymosis	2 (2.2%)
— Failed cannulation	3 (3.3%)
— Conversion to ultrasound-guided method	3 (3.3%)

Time was measured from skin puncture to confirmation of arterial waveform. Ease of cannulation was operator-reported.

On subgroup analysis by BMI, patients with BMI <25 kg/m² had the highest first-attempt success rate (82.4%), followed by those with BMI 25–29.9 kg/m² (65.9%) and ≥30 kg/m² (42.9%), with the difference being statistically significant ($p = 0.012$). The mean number of attempts increased progressively with BMI (1.21 ± 0.52 vs. 1.48 ± 0.71 vs. 2.07 ± 0.83; $p = 0.004$), as did the mean time to successful cannulation (53.2 ± 13.1 s, 63.5 ± 15.3 s, and 78.6 ± 21.7 s respectively; $p < 0.001$). The incidence of difficult cannulation was significantly higher in the obese group (35.7%) compared to the normal (5.9%) and overweight (15.9%) groups ($p = 0.009$) (Table 3).

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Table 3: Association Between BMI and Cannulation Outcomes (n = 92).

Outcomes	BMI Category (kg/m²)			P-value
	<25 (n=34)	25 – 29.9 (n=44)	⩾ 30 (n=14)	
First-Attempt Success	28 (82.4%)	29 (65.9%)	6 (42.9%)	0.012
Mean Attempts	1.21 ± 0.52	1.48 ± 0.71	2.07 ± 0.83	0.004
Mean Time (s)	53.2 ± 13.1	63.5 ± 15.3	78.6 ± 21.7	<0.001
Difficult Cannulation	2 (5.9%)	7 (15.9%)	5 (35.7%)	0.009

BMI classification follows WHO Asia-Pacific guidelines. Time to cannulation = time from skin puncture to waveform confirmation.

Patients with a strong radial pulse had significantly better cannulation outcomes compared to those with a weak pulse. The first-attempt success rate was higher in the strong pulse group (76.1%) than in the weak pulse group (42.9%) ($p = 0.008$). The mean number of attempts was significantly lower in patients with strong pulses (1.32 ± 0.63 vs. 2.00 ± 0.84; $p < 0.001$), as was the mean time to successful cannulation (58.6 ± 15.2 s vs. 76.5 ± 20.4 s; $p < 0.001$). Additionally, the incidence of difficult cannulation was markedly higher in the weak pulse group (42.9%) compared to those with strong pulses (7.0%) ($p < 0.001$) (Table 4).

Table 4: Influence of Pulse Strength on Cannulation Outcomes (n = 92).

Outcomes	Pulse Strength		P-value
	Strong (n = 71)	Weak (n = 21)	
First-Attempt Success	54 (76.1%)	9 (42.9%)	0.008
Mean Attempts	1.32 ± 0.63	2.00 ± 0.84	<0.001
Mean Time (s)	58.6 ± 15.2	76.5 ± 20.4	<0.001
Difficult Cannulation	5 (7.0%)	9 (42.9%)	<0.001

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Pulse strength was assessed subjectively by the anaesthesiologist prior to cannulation. Pulse volume was subjectively assessed by the anaesthesiologist during palpation.

Complications were observed in 9 out of 92 patients (9.8%). The most common complication was hematoma, occurring in 4 patients (4.3%), followed by arterial spasm and bruising/ecchymosis in 2 patients each (2.2%).Failed cannulation requiring more than three attempts was noted in 3 cases (3.3%), all of which were subsequently converted to ultrasound-guided cannulation (3.3%) (Table 5).

Table 5:Complications Observed During Cannulation Attempts (n = 92).

Complication Type	Frequency	Percentage
Hematoma	**4**	**4.3%**
Arterial spasm	**2**	**2.2%**
Bruising/ecchymosis	**2**	**2.2%**
Failed cannulation	**3**	**3.3%**
Conversion to ultrasound	**3**	**3.3%**

On multivariate analysis, two independent predictors were significantly associated with difficult radial artery cannulation. Patients with a BMI ≥30 kg/m² had nearly five times higher odds of difficult cannulation compared to those with BMI <25 kg/m² (AOR: 4.82; 95% CI: 1.28–18.14; p = 0.020). Similarly, the presence of a weak radial pulse was associated with over seven times increased odds of difficulty (AOR: 7.26; 95% CI: 2.20–23.99; p = 0.001). Other variables such as age ≥60 years, ASA II status, female sex, lower systolic blood pressure, and diabetes mellitus were not statistically significant predictors (Table 6).

Table 6:Binary Logistic Regression Analysis of Predictors of Difficult Radial Artery Cannulation (n = 92).

Predictor Variable	Adjusted Odds Ratio (AOR)	95% Confidence Interval (CI)	p-value
BMI ⩾ 30 kg/m² (vs. <25)	**4.82**	**1.28 – 18.14**	**0.020**
Weak pulse (vs. strong)	**7.26**	**2.20 – 23.99**	**0.001**
Age ⩾ 60 years (vs. <60)	**1.94**	**0.56 – 6.68**	**0.292**
ASA II (vs. ASA I)	**1.18**	**0.42 – 3.28**	**0.752**
Female sex (vs. male)	**1.36**	**0.49 – 3.76**	**0.554**
Systolic BP < 110 mmHg (vs. ⩾110)	**2.41**	**0.78 – 7.48**	**0.123**
Diabetes mellitus (yes vs. no)	**1.72**	**0.51 – 5.85**	**0.376**

Outcome variable: Difficult cannulation (operator-graded); Reference categories: BMI <25 kg/m², strong pulse, age <60 years, ASA I, male sex, SBP ≥110 mmHg, non-diabetic; Model goodness-of-fit: Hosmer–Lemeshow test p = 0.684; Nagelkerke R^2 = 0.327.

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Discussion

The present study aimed to evaluate the ease and success of radial artery cannulation using the palpation method in patients undergoing surgery under general anaesthesia. A total of 92 adult patients were assessed, yielding a first-attempt success rate of 68.5% and an overall cannulation success rate (within 3 attempts) of 96.7%. The first-attempt success rate observed in our study is comparable to previously reported values. Brzezinski et al., in a comprehensive review, noted a first-pass success rate of 65–70% for radial artery cannulation by palpation [10]. Bhattacharjee et al., reported a 72% first-attempt success rate using palpation in adult emergency patients, while Gu et al., in a meta-analysis, indicated a pooled success rate of 68% for the first attempt using landmark techniques [11,12]. The high overall success rate of 96.7% in our cohort is reassuring, reflecting the proficiency of trained anaesthesiologists and appropriate patient selection.

Our analysis revealed a mean cannulation time of 62.4 ± 18.9 seconds, with an average of 1.45 ± 0.69 attempts per patient. These figures align with previous study by Tiru et al., suggesting that when performed by experienced hands, the palpation method achieves acceptable efficiency [13]. However, the procedure's effectiveness appeared significantly influenced by patient-related factors such as BMI and pulse strength.

The study identified BMI ≥30 kg/m² as a significant determinant of poor cannulation outcomes. First-attempt success declined notably from 82.4% in normal-weight individuals to 42.9% among obese patients ($p = 0.012$), with a concurrent increase in mean attempts and cannulation time. This trend mirrors findings from Nordstrand et al., who reported that obesity adversely affected arterial palpation due to increased subcutaneous tissue thickness, impairing the ability to accurately localize the vessel [14]. Similarly, Thailamuthu et al., demonstrated significantly lower first-pass success rates among obese patients, suggesting the need for alternative techniques in this population [15].

Obesity not only impairs the tactile detection of arterial pulsation but also alters vascular anatomy, increasing the depth and tortuosity of the artery, making needle advancement and catheter insertion more challenging [16]. Our regression analysis confirmed that patients with BMI ≥30 kg/m² had 4.82 times greater odds of difficult cannulation ($p = 0.020$), underscoring the need for heightened clinical awareness and possibly early use of ultrasound in this subgroup.

Pulse strength emerged as another key predictor of cannulation difficulty. Patients with a weak palpable pulse had significantly lower first-pass success (42.9%) compared to those with a strong pulse (76.1%) ($p = 0.008$). This is consistent with data from Gutte et al., who demonstrated that weak or thready pulses, particularly in hypotensive or elderly patients, are associated with significantly lower success rates using palpation [17]. Furthermore, our logistic regression showed that weak pulse increased the odds of difficult cannulation by 7.26 times ($p = 0.001$), making it the most robust predictor in our model.

This finding has practical clinical implications. In patients with low cardiac output or peripheral vasoconstriction—commonly encountered in perioperative or critically ill settings—the radial pulse may be poorly palpable despite being patent [18]. In such scenarios, continuing multiple blind attempts can increase the risk of complications. Early identification of a weak pulse should prompt consideration for ultrasound-guided cannulation, which has been shown in multiple studies, including those by Cho et al., and Chanthawong et al., to significantly improve success rates and reduce complications in such high-risk patients [19,20].

The overall complication rate was 9.8%, which is within the range reported in the literature (5–15%) for palpation-based cannulation. The most common complications observed were hematoma (4.3%), arterial spasm (2.2%), and ecchymosis (2.2%), while 3 patients (3.3%) required conversion to ultrasound-guided technique due to failed cannulation. These findings are consistent with the observations by Menon et al., who reported hematoma rates of 5–10% and spasm in approximately 2–4% of patients following multiple failed attempts [21]. The relatively low rate of serious complications in our study may be

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attributed to the experience of the operators and adherence to maximum attempt thresholds [22].

It is important to note that repeated cannulation attempts are independently associated with increased complication rates. This has been highlighted by multiple studies, including that of Nadagoudar et al., and Rao et al., which showed a threefold increase in hematoma formation beyond the third attempt [23,24]. Therefore, we recommend that no more than 3 attempts be made using the palpation method, beyond which ultrasound guidance should be promptly employed.

Strengths and Limitations

The strength of this study lies in its focus on real-world application of the palpation method by experienced anaesthesiologists in a controlled surgical setting, along with robust subgroup analyses by BMI and pulse strength. However, the study has several limitations. First, it was a single-center study, limiting generalizability. Second, we did not compare palpation directly with ultrasound guidance in a randomized manner, which could have more definitively identified the superiority of one approach over the other. Third, operator-dependent variations in palpation technique and subjective assessment of ease or pulse volume may introduce interobserver variability.

Despite these limitations, the study provides valuable insights into the utility of the palpation technique in clinical practice and the patient factors that predict success or failure. Our findings are particularly relevant in resource-constrained environments, where ultrasound devices may not be universally available, and clinical decision-making must be tailored based on readily available predictors.

Conclusion

Radial artery cannulation using the palpation method remains a clinically viable technique with high success rates in appropriately selected patients. However, elevated BMI and weak pulse significantly reduce the likelihood of first-attempt success and increase the risk of difficult cannulation. In such patients, early consideration of ultrasound guidance is advisable to minimize attempts and prevent complications.

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