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Comparison of Ultrasound-Guided and Palpation Techniques for Radial Artery Cannulation

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Abstract

Background: Radial artery cannulation is a routine procedure performed in operating rooms and intensive care units for continuous blood pressure monitoring and arterial blood gas analysis. Among the various techniques available, ultrasound-guided (USG) and palpation methods are commonly used. This study aimed to compare the success rate, average time for successful cannulation, first-attempt success rate, and complication rates between the USG-guided and palpation techniques for radial artery cannulation.

Methods: A comparative cross-sectional study was conducted at Kathmandu Medical College Teaching Hospital, involving 52 patients aged 19 to 77 years with American Society of Anesthesiologists (ASA) physical status I–IV undergoing major surgery. Participants were randomly allocated into two equal groups. In Ultrasound group cannulation using ultrasound guidance, similarly in palpation group cannulation performed by the palpation method. Demographic characteristics, baseline vital signs, time required for successful cannulation, number of attempts, success or failure, and complications (mainly hematoma) present or absent were noted.

Results: There were no significant differences in demographic characteristics or baseline vital signs between the groups. The overall success rate was identical in both groups (96.2%vs 96.25) and was not statistically significant (p>0.05). Average time for successful cannulation were similar (59sec vs 60sec) (p = 0.808). There was higher first attempt success rate in ultrasound group compared with palpation. {(61.8% vs. 30.8%) P=0.026}.The median number of attempts for successful cannulation were less in USG guided group compared to palpation group i.e. {1(1, 2) vs. 2(1,3)} (p=0.024).There were fewer underlying hematoma in ultrasound guided group i.e. 11.5% vs. 30.8% but that was statically non-significant (p=0.090).

Conclusion: In our study, there was similar time duration for successful cannulation and overall success rate for both groups. However, there was a higher first attempt success rate, the fewer number of cannulation attempts in ultrasound guided method compared to the palpation method.

Novelty: This study highlights the clinical advantage of ultrasound guidance in improving the efficiency of radial artery cannulation by increasing the likelihood of first-attempt success and reducing the number of attempts, supporting its wider adoption in perioperative and critical care settings.

Keywords: arterial cannulation; invasive monitoring; monitoring technique; ultrasound.

Introduction

American Society of Anesthesiologist (ASA) recommends blood pressure (BP) monitoring as mandatory monitoring among the standard monitors during anesthesia (Klein et al., 2021). BP can be measured by noninvasive techniques (NIBP) or by invasive measures which is commonly known as intra-arterial blood pressure (IABP). For IABP monitoring we have to cannulate one of the peripheral arteries and the radial artery is one of the commonly used among these (Yeap et al., 2019).

Apart from continuous beat to beat BP monitoring; it can be used to monitor cardiac output, pulse pressure variation, stroke volume variation if the appropriate software is used and sampling port for arterial blood gas analysis as well (Jones & Pratt, 2009).There are many inaccuracies of NIBP measurement during long term anesthesia and in critically ill patients. It is better if we can use IABP in all anesthetized patients for better results (Scheer et al., 2002).

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But arterial cannulation and IABP measurement needs extra instruments and costs which may be inconvenient in every routine surgery in our setup. Therefore we used IABP monitoring for very major surgeries where there might have been an excessive fluid shift, blood loss, and hemodynamic instability and in critically ill cases in the perioperative period and intensive care units as well (Scheer et al., 2002).

History regarding the performance of arterial cannulation is unclear but the first recorded cannulation of an arterial blood vessels was performed in 1714 by the English Reverend, Stephen Hales by inserting the tubes directly into the arteries of animals. The first description of arterial cannulation in a human was done in 1856, when blood pressure measurement was done in the femoral artery (Booth, 1977).

In 1949 an arterial line in the brachial artery with a small plastic catheter and performed the continuous monitoring of arterial blood pressure (Tiru&Bloomstone, 2012).The choice of method depends on preference side, operator preference and available equipment. Intra-arterial blood pressure measurement is more accurate than by noninvasive means, permits the rapid recognition of blood pressure changes that is very important in hemodynamically unstable patient and patients with vasoactive drugs. When rapid changes in blood pressure are anticipated (due to cardiovascular instability, large fluid shifts or pharmacological effects) or when non-invasive blood pressure monitoring is not possible or likely to be inaccurate (obesity, arrhythmias such as atrial fibrillation, non-pulsatile blood flow during cardiopulmonary bypass), invasive blood pressure is very useful (Ward & Langton, 2007).

The insertion of radial artery catheters is traditionally performed using the palpation method as a guide to placement, however some patients requiring arterial lines may be hypotensive, obese, oedematous, have a weak and missing pulse, resulting in difficulty in palpation of pulse. On the other hand, the catheter may not be cannulated successfully even with good blood return in the first attempt or the artery may develop spasm resulting in difficulty in further attempts (Shiver et al., 2006). In these situations ultrasonic guidance is very helpful for arterial cannulations.

The radial artery is one of the most preferred sites for arterial cannulation as it is located superficially, has presence of collateral supply through the ulnar artery and has a low incidence of complications (<1%) (Yeap et al., 2019). Ultrasound image (USG) can visualize the arterial lumen and catheter inside the artery and any complications can be identified immediately and managed as well (Nasreen et al., 2016).

The radial artery is a terminal branch of brachial artery. It runs inferolateral under brachioradialis, lies lateral to flexor carpi radialis tendon in the distal forearm. It supplies the palmar arches of the hand. It is palpable at the wrist, proximal to the radial styloid or radial head. The cannulation site should be at the very distal portion of the arm. The most frequent location for cannulation of the radial artery is at the proximal flexor crease of the wrist, one cm proximal to the styloid process (Moore et al., 2014).

Intra-arterial blood pressure (IABP) measurement is often considered as gold standard as it allows the continuous beat to beat pressure measurement in patient under vasoactive drugs.

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The waveform that is displayed in A-line may be analyzed for detailed study of the further cardiovascular system (pulse contour analysis) (Jones & Pratt, 2009).Digital palpation method was/is used commonly for arterial cannulation before the introduction of vascular cannulation by USG use. Palpation methods may need multiple attempts, longer duration and may result in arterial spasm and hematoma.

Supporting above perspective, the study designed to compare the success rates between ultrasound-guided and traditional palpation techniques for radial artery cannulation.

Research Methodology

This study employed a comparative cross-sectional design to evaluate the effectiveness of ultrasound-guided radial artery cannulation versus the traditional palpation method. The research was conducted in the Department of Anaesthesiology and Critical Care at Kathmandu Medical College Teaching Hospital, Sinamangal, over a period of 11 months (August 19, 2020, to July 30, 2021). The study population included adult patients (aged >18 years) undergoing major surgeries under general anesthesia, classified as ASA grade I-IV. Exclusion criteria comprised patients with negative modified Allen's test, peripheral vascular disease, coagulopathy, infection at the cannulation site, burns, or recent catheterization.

A sample size of 52 patients (26 per group) was determined using a power analysis with 95% confidence interval ($Z1\text{-}\alpha = 1.96$), 90% power ($Z1\text{-}\beta = 1.28$), and a pooled standard deviation of 19.23 seconds derived from previous studies. The clinically acceptable margin (δo) was set at 10 seconds, with an expected mean time difference (δ) of 22.2 seconds between the two techniques. Randomization was achieved using a computer-generated random number table, dividing participants into Group U (ultrasound-guided) and Group P (palpation method).

Data collection followed a structured protocol. Pre-anesthetic evaluations were conducted, and written informed consent was obtained. Patients were prepared with standard ASA monitoring, including non-invasive blood pressure, ECG, and pulse oximetry. General anesthesia was induced using midazolam, propofol, fentanyl, and vecuronium, followed by endotracheal intubation. For Group U, a 7.5Hz linear ultrasound probe was used to visualize the radial artery before cannulation, while Group P relied on digital palpation. The time taken for successful cannulation, number of attempts, first-attempt success rate, and overall success rate were recorded.

The primary outcome measures included cannulation time, first-attempt success, and total success rate, with failure defined as inability to cannulate within five attempts. Statistical analysis compared the efficiency and reliability of both techniques, providing insights into the optimal approach for radial artery cannulation in surgical settings.

Results

The study included 52 patients undergoing elective major surgeries, evenly distributed between Group U (ultrasound-guided radial artery cannulation, n=26) and Group P (palpation method, n=26). The age distribution ranged from 19 to 77 years, with a mean age of 50 ± 16.85 years

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in Group U and 52 ± 16.85 years in Group P, showing no significant difference between the groups (p = 0.169). Age stratification revealed 12 patients (23.1%) aged ≤35 years, 12 (23.1%) aged 36–50 years, 14 (26.9%) aged 51–65 years, and 14 (26.9%) aged ≥66 years, indicating a balanced distribution across age categories.

Regarding gender distribution, males constituted 59.6% (n=31) of the total participants, while females accounted for 40.4% (n=21). In Group U, the male-to-female ratio was 16:10 (61.5% vs. 38.5%), whereas in Group P, it was 15:11 (57.7% vs. 42.3%). The difference in gender distribution between the two groups was not statistically significant (p = 0.777).

Statistical analysis was performed using SPSS version 21, with categorical variables (gender, first-attempt success rate, hematoma occurrence) analyzed using the Chi-square test. A p-value of <0.05 was considered statistically significant for all comparisons. The demographic data confirmed that both groups were well-matched in terms of age and gender, minimizing potential confounding factors in the comparative analysis of cannulation techniques.

Table 1: ASA PS distribution of patients enrolled in the study

American Society of Anesthesiologists Physical Status	**Groups**		**p-value**
	Group U	**Group P**	
ASA-I	11(42.3%)	8(30.8%)	0.450
ASA-II	15(57.7%)	17(65.4%)	
ASA-III and above	0(0%)	1(3.8%)	

In ultrasound group (Group U), 42.3% patients were in ASA I, 57.7% were in ASA II and none of the patient were in ASA III and above. In palpation group (Group P), 30.8% were in ASA I, 65.4% were in ASA II and 3.8% were in ASA III and above. There was no statistically significant difference between group in ASA PS distribution (p =0.450).

Table 2: Weight distribution of patients enrolled in the study

	Methods		**P value**
	Group U	**Group P**	
Median weight of patients	53(50,58)	50(45,59)	0.283

The median weight of patients enrolled in Group U was 53 and Group P was 50. However there was no statistically significant difference between group in weight distribution (p=0.282).

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Table 3: BMI of patient enrolled in study

BMI (kg/m2)	Group U	Group P	Total	P- value
<18.5	6	6	12(23%)	0.934
18.5-24.9	17	16	33(63%	
25-29	1	3	4(7.6%)	
>30	2	1	3(5.7%)	
Total	26(50%)*	26(50%)*	52(100%)*	

*= % within Body mass index category

The most number of patients who underwent arterial cannulation for IABP were BMI of 18.5 to 24.9 kg/m2. Among Group U six patients had BMI less than 18.5kg/m2, 17 patients had BMI 18.5 -24.9 kg/m2, one each in 25-29kg/m2 and two had BMI more than 30kg/m2. Six patients in Group P had BMI less than 18.5kg/m2, 16 patients had BMI 18.5 -24.9 kg/m2, three each in 25-29kg/m2, one each of them more than 30kg/m2. There was no statistically significant difference between groups in Body mass index category (p= 0.934).

Table 4: Baseline systolic blood pressure of patient enrolled in study

Baseline systolic blood pressure category (mm of Hg)ϕ	Groups		Total	Percentage among total
	Group U	Group P		
Normal (<120)	10(38.46%)*	14(53%)*	24	46.15%
Prehypertension (120-130)	9(34.61%)*	4(15.38%)*	13	25%
Stage I (140-159)	5(19.23%)*	6(23.07%)*	11	21.15%
Stage II (≥160)	2(7.69%)*	2(7.69%)*	4	7.69%
Total	26(100%)	26(100%)	52	100%

* = % within the group
ϕ JNC -8 classification of HTN

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Table 5: Median value of baseline systolic blood pressure of patient enrolled in study

	Group U	Group P	p-value
	Median Value (mm Hg)	**Median value (mm Hg)**	0.404
Systolic Blood pressure	125 (110,140)	118 (110,140)	

In our study, 38.46% of patients among Group U, had normal baseline systolic blood pressure, 34.61% had 120-130 mm of Hg, 19.23% had 140-159mm of Hg and 7.69% with blood pressure more than 160 mmg of Hg. Similarly in Group P, 53% had normal baseline blood pressure, 15.38% had 120-130mm of Hg, 23.07% had 140-159mm of Hg and 7.69% more than 160mm of Hg.

In group U the median value of systolic blood pressure was 125mm of Hg and 118 mm of Hg in group P. Systolic blood pressure distribution was same across the categories of methods (P= 0.404).

Table 6: Baseline Heart Rate of the patient enrolled in the study

Heart Rate Category (bpm)	Group U	Group P	Total
Bradycardia (<60)	2(7.69%)	2(7.69%)	4(7.69%)
Normal(60-100)	17(65.38%)	15(57.69%)	32(61%)
Tachycardia(>100)	7(26.92%)	9(34.61%)	16(30.76%)
Total	26(50%)	26(50%)	52(100%)

The heart rate of patients enrolled in the study were from 55 bpm to 120 bpm.In group U, 65.38 % patients had normal baseline heart rate, 7.69% patients had bradycardia and 26.92% had tachycardia at the time of cannulation. In the same way in group P, 57.69% patients had normal baseline heart rate, 7.69% had bradycardia and 34.61% had tachycardia at the time of cannulation.

Table 7: Median value of baseline heart rate of patient enrolled in study

	Group U	Group P	P value
	Median value	**Median value**	0.829
Heart Rate	80(68,100)	85(74,105)	

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The median heart rate in group U was 80bpm and group P is 85 (P = 0.829).The distribution of Heart rate was same across the categories of methods.

Table 8: Success and failure rate

Groups	Success /failure rate		Total	P-value
	Success	Failure		
Group U	25(96.2%)	1(3.8%)	26 (100%)	1.0
Group P	25(96.2%)	1(3.8%)	26(100%)	
Total	50(96.2%)	2(3.8%)	52(100%)	

The overall success rate was 96.2% and failure percentage rate 3.8% in both groups. (P = 1.0). Overall success rate of both groups were similar so method wise there was no difference between the groups and it was not statistically significant.

Table 9: Average time for successful cannulation

	Group U	Group P	P value
	Median Value (seconds)	Median Value (Seconds)	
Average time for successful cannulation	59(35,115)	60(42,120)	0.808

The median value of average time for successful cannulation was comparatively less in group U compared with group P (59sec Vs 60sec). However it was not statistically significant between two groups (P =0.808).

Table 10: First attempt success rate

Groups	First Attempt success rate		Total	P-value
	Yes	No		
Group U	16(61.5%)	10(38.5%)	26(100%)	0.026*
Group P	8(30.8%)	18(69.2%)	26(100%)	
Total	24(46.2%)	28(53.8%)	52(100%)	

*= Significant

Successful cannulation at first attempt was 61.5% in group U (16 out of 26) and 30.8% in group P (8 out of 26). Failure in first attempt was 38.5% in Group U and 69.2% in group P .The first attempt success rate was higher in group U compared to group P which was statistically significant as well (p = 0.026).

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Table 11: Number of attempts for successful cannulation

	Group U	Group P	P value
	Median Value	Median Value	
Number of attempts	1(1,2)	2(1,3)	0.024*

***= significant**

The median value of number of attempts between group U was one and group P was two. It was statistically significant (P = 0.024). Ultrasound guided group has fewer number of attempts for successful cannulation than palpation group.

Table 12: No of cannula used

	Group U	Group P	P value
	Median Value	Median Value	
No of Cannula	1 (1,2)	2(1,2)	0.10

The number of arterial cannula used during IABP monitoring were compared between two groups .The median value of number of cannula in USG guided group was one and palpation group was two. Though there were fewer number of cannula used in Ultrasound guided group (Group U) compared to palpation group (Group P), this finding was statistically not-significant (p=0.10).

Table 13: Complications during arterial cannulation for IABP

	Hematoma		P-value
	Present	Absent	
Group U	3(11.5%)	23(88.5%)	0.090
Group P	8(30.8%)	18(68.2%)	

Though other complications couldn’t be studied, we studied hematoma after the IABP cannulation. Our study showed that more number of cannulation site hematoma in palpation group compared to USG group (30.8% vs. 11.5%), these finding were statistically non-significant (p=0.090).

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Discussion

This comparative study evaluated ultrasound-guided (USG) versus palpation techniques for radial artery cannulation in patients undergoing elective major surgeries, with 52 participants equally divided into two groups. Demographics including age, gender, ASA PS classification, weight, BMI, baseline systolic blood pressure, and pulse rate were comparable between groups (p>0.05). The time required for successful cannulation and overall success rates showed no significant differences (p=0.808 and p=1.0, respectively). However, the USG group had a higher first-attempt success rate (61.5% vs. 30.8%, p=0.026), fewer arterial punctures (p=0.024), and required fewer cannulas (median one vs. two, p=0.10) compared to the palpation group.

One of the key aims was to compare success and failure rates, both of which were similar across groups (success: 96.2%; failure: 3.8%; p=1.0), echoing the findings of Tangwiwat et al. in neurosurgical patients, where USG showed no added benefit, likely due to operator inexperience. It is widely acknowledged that USG cannulation improves outcomes when performed by skilled operators (Troianos et al., 2012). Our study did not use the Seldinger technique Shiver et al.(2006), which, when paired with a guidewire, can enhance success rates, especially for novices.

The average time for successful cannulation (USG: 59 sec; palpation: 60 sec) was not significantly different (p=0.808), aligning with earlier Japanese and Danish studies that found no time benefit using USG (Tada et al., 2003; Hansen et al., 2014). However, USG significantly improved first-attempt success and reduced the number of attempts, though findings may lack generalizability due to single-operator use. Ganesh et al. similarly found in a pediatric study that, while USG may slightly prolong insertion time, it reduces the number of required attempts, leading to an overall more efficient and successful process (Ganesh et al., 2009).

Common palpation technique failures included difficulty advancing the catheter despite visible flashback, often due to tangential entry, tortuosity, or spasm. Posterior wall impingement may still allow guidewire insertion, suggesting benefits of USG in such scenarios.

Our results showing improved first-attempt success with USG (61.5%) versus palpation (30.8%, p=0.026) were consistent with studies by Levin et al. (2003)[p=0.03] and Shiver et al.(2006), who observed fewer attempts and anatomic sites needed using USG. However, Nasreen et al. noted a non-significant difference in first-attempt success (72% vs. 64%; p=0.391). Learning curves and real-time imaging skill significantly impact USG effectiveness, as noted by Sites et al., who emphasized proper training.

Limitations in Peter et al.(2015)study were due to reliance on cross-sectional imaging; our study and Shiver et al.'s used longitudinal views, which enhanced visualization and success. Wang et al. also supported using modified long-axis USG for better outcomes (Jones & Pratt, 2009). Similarly, Levin et al. (2003)reported first-attempt success in 62% of USG cases versus 34% in palpation (p=0.03), showing that portable USG improves efficiency and reduces attempts required.

Overall success rates for USG in adults range from 62–87% (vs. 34–50% with palpation)Shiver et al.(2006);Ammar et al.(2017);Levin et al.(2003), and 14–67% in pediatrics (vs. 14–20%) (Ganesh et al., 2009). Despite potentially taking slightly longer per attempt, USG compensates with fewer total attempts, supporting our results.

Our study showed fewer attempts in the USG group (median one vs. two; p=0.024), similar to findings by Nasreen et al. (1.4 ± 1.0 vs. 2.0 ± 0.7; p=0.001), Ammar et al. (1.16 ± 0.37 vs. 1.44 ± 0.67; p=0.025), and Shiver et al. (1.2 vs. 2.2; p=0.001). These fewer attempts likely reduced patient discomfort and complications. While Levin et al. endorsed USG in perioperative settings, its benefit in critically ill or hypotensive patients remains less clear.

Our use of a 7.5 MHz linear transducer may have helped reduce attempts, as higher frequency improves superficial imaging. During IABP monitoring, fewer cannulas were used in the USG group (one vs. two; p=0.10), likely due to fewer failed attempts. We did not analyze failed attempt durations due to undefined termination criteria, but successful cannulation times were consistently measurable.

Conclusion

This study compared the ultrasound-guided (USG) technique with the traditional palpation method for placing a cannula in the radial artery to monitor invasive blood pressure. The time taken and overall success rates were similar for both methods. However, the USG-guided technique had a higher success rate on the first attempt, required fewer attempts on average, and used fewer cannulas compared to the palpation method.

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