Section: Anesthesiology

Original Research Article

COMPARISON OF RADIAL ARTERY CANNULATION USING ULTRASOUND GUIDANCE VERSUS PALPATORY TECHNIQUE: A RANDOMISED CONTROLLED TRIAL

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ABSTRACT

Background: Radial arterial cannulation is a commonly performed in operating rooms and intensive care units for invasive blood pressure monitoring and arterial blood gas sampling. Although the conventional palpatory technique remains widely practiced, ultrasound guidance has emerged as a promising alternative that may improve procedural success and reduce complications. This study was designed to compare ultrasound-guided radial artery cannulation with the conventional palpatory technique in adult patients requiring arterial cannulation. **Materials and Methods:** This prospective, parallel-group, randomized controlled trial included 102 adult patients requiring radial artery cannulation in the operating theatre or intensive care unit. Participants were randomly allocated in a 1:1 ratio to either ultrasound-guided (US group, n=51) or palpatory technique (PL group, n=51). The primary outcome was first-attempt success rate. Secondary outcomes included procedure time, number of attempts, needle redirections, failure rate, cannulation site change, and complications including hematoma, vasospasm, and posterior wall puncture. **Results:** The first-attempt success rate was significantly higher in the ultrasound group compared with the palpation group (80.4% vs. 60.8%; p=0.03). Mean procedure time was significantly shorter in the ultrasound group (30.1 ± 32.4 seconds vs. 88.1 ± 91.4 seconds; p<0.001). The ultrasound group required fewer attempts (1.2 ± 0.5 vs. 1.5 ± 0.6; p=0.024) and fewer redirections (0.24 ± 0.51 vs. 0.76 ± 0.67; p=0.001). Rates of hematoma (19.6% vs. 33.3%) and posterior wall puncture (7.8% vs. 19.6%) were lower in the ultrasound group, although differences were not statistically significant. No participant required a change of cannulation site. **Conclusion:** Ultrasound-guided radial artery cannulation significantly improves first-pass success and procedural efficiency while reducing needle manipulations compared with the palpatory technique. Routine incorporation of ultrasound guidance may improve the quality and safety of arterial cannulation in adult patients.

INTRODUCTION

Background and Rationale

Radial artery cannulation is an essential procedure in anesthesiology and critical care practice. It facilitates continuous invasive arterial pressure monitoring, repeated arterial blood gas analysis, and hemodynamic assessment in critically ill patients and those undergoing major surgical procedures.[1,2] Despite being considered a routine procedure,

arterial cannulation can be technically challenging and may be associated with multiple attempts, procedural delays, and complications such as hematoma formation, vasospasm, thrombosis, and posterior wall puncture.[3]

Traditionally, radial artery cannulation is performed using anatomical landmarks and palpation of the arterial pulse. Although widely practiced, the palpatory technique has limitations, particularly in patients with obesity, oedema, hypotension, peripheral vascular disease, or anatomical variations. Such factors may contribute to lower first-pass success rates and increased procedural complications.[3]

Point-of-care ultrasonography has transformed vascular access procedures. Ultrasound provides real-time visualization of vascular structures, enabling identification of vessel anatomy, surrounding tissues, and needle trajectory. Several studies have demonstrated improved success rates and reduced complications with ultrasound-guided vascular access. Professional organizations and experts advocate the use of ultrasound guidance for vascular access procedures.[4]

Multiple randomized trials have reported superior first-pass success rates and shorter procedural times with ultrasound-guided radial artery cannulation. Shiver et al. demonstrated a first-pass success rate of 87% using ultrasound guidance compared with 50% using palpation.[5]

Similar findings have been reported by Kiberenge et al., Levin et al., and several meta-analyses evaluating radial artery cannulation. [6-8]

However, evidence from adult surgical and intensive care populations remains relatively limited, particularly in the Indian setting. Therefore, this randomized controlled study was undertaken to compare ultrasound-guided radial artery cannulation with the conventional palpatory technique in adult patients requiring arterial cannulation.

MATERIALS AND METHODS

Study design: This study was a single center prospective, parallel-group, randomized controlled trial conducted between October 2018 and May 2019 at a South Indian Hospital after Institutional Ethics committee clearance involving adult surgical and intensive care patients aged between 18-70 years, requiring radial artery cannulation after taking informed consent. Patients with bleeding disorders, local infection, local injury, or a positive modified Allen's test were excluded.

The primary objectives were to compare the first attempt success rate of radial artery cannulation using point-of-care ultrasound versus conventional palpatory technique. The secondary objectives were to compare the number of attempts, procedure time, redirection, and failure rate, complications such as hematoma, vasospasm, posterior wall puncture and change of cannulation site.

Sample Size: The sample size was calculated based on findings reported by Shiver et al., who observed first-attempt success rates of 87% and 50% in ultrasound and palpation groups, respectively [5]. Assuming a power of 90% and a two-sided alpha of 0.05, the required sample size was calculated as 92 participants.

$$n = f(\alpha/2, \beta) \times [p_1 \times (100-p_1) + p_2 \times (100-p_2)] / (p_2-p_1)^2$$

To account for a 10% dropout rate, the sample size was increased to 102 participants. Eligible patients were block randomized randomly into two groups:

1. Ultrasound-guided group (US)
2. Palpation group (PL)

Randomization was performed using computer-generated block randomization with block sizes of ten. Participants were not aware of allocation to trail group till the start of intervention. Both the operators and the participants did not have access to random allocation sequence. Due to the nature of the intervention, operator blinding was not feasible. Outcome assessment was based on predefined objective procedural parameters. Cannulations were performed by anesthesiology consultants or trainees who had previously performed at least ten radial artery cannulations using both techniques.

On the day of the surgery, Patients were shifted to Operation Theater and under standard monitoring and functional intravenous catheter; arterial lines were placed after local infiltration with 2% inj. lignocaine. In Intensive care unit also same procedure was followed. BD arterial catheter was used.

Group US: A sterile-covered 3-12 MHz linear ultrasound probe was used to identify the radial artery. After obtaining a short-axis image, the probe was rotated to obtain a long-axis view. Cannulation was then performed using a long-axis in-plane approach under real-time ultrasound guidance.

Group PL: After sterile preparation, the radial artery was identified by palpation and cannulated using the conventional landmark-guided technique.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Independent t-tests were used for continuous variables and chi-square tests for categorical variables. Statistical significance was defined as $p<0.05$. Analysis was performed using SPSS version 26.0.

RESULTS

A total of 102 patients were enrolled and randomized equally into the ultrasound group (n=51) and palpation group (n=51). [Figure 1]

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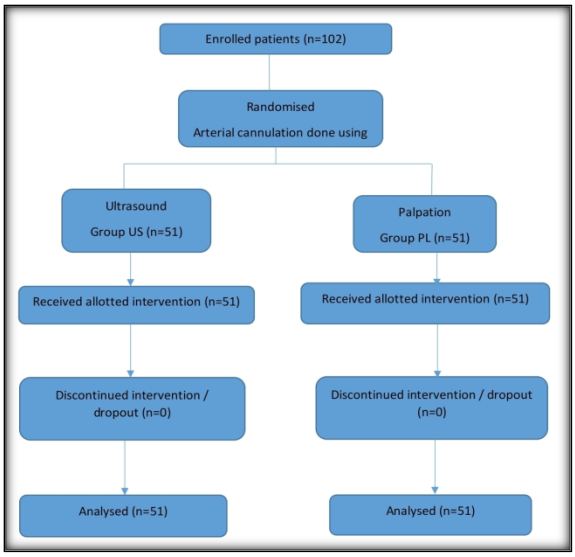

Figure 1: Consort flow chart showing allotment, intervention and analysis of the study participants.

Baseline demographics:
The mean age was 53.8 ± 17.4 years in the ultrasound group and 57.2 ± 16.2 years in the palpation group. The difference was not statistically significant (p=0.275). [Figure 2]

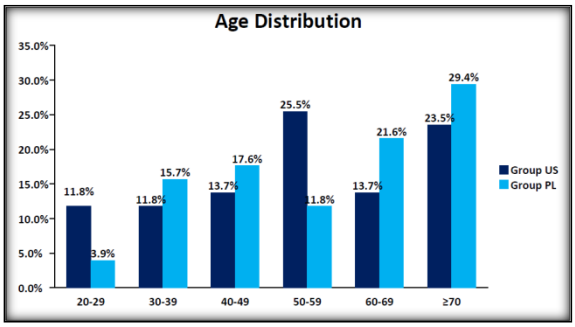

Figure 2: Distribution of patients based on age between the study groups

Gender: Male participants constituted 66.7% of the ultrasound group and 58.8% of the palpation group. Gender distribution was similar between groups (p=0.413). [Figure3]

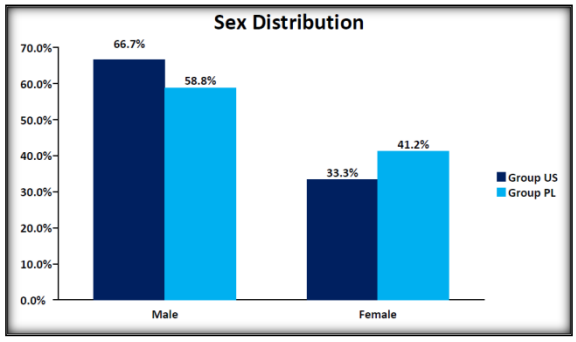

Figure 3: Distribution of patients based on gender into two study groups

Primary Outcome:
First-Attempt Success Rate: The ultrasound group demonstrated a significantly higher first-attempt success rate compared with the palpation group (80.4% vs. 60.8%; p=0.03). [Figure 4]

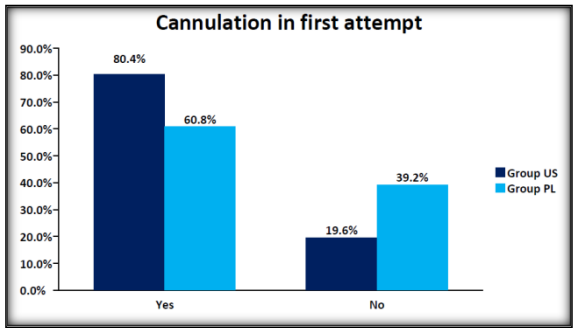

Figure 4: First attempt success percentage between the study groups

Secondary Outcomes
Procedure Time: The mean procedure time was significantly shorter in the ultrasound group (30.1 ± 32.4 seconds) compared with the palpation group (88.1 ± 91.4 seconds; p<0.001). [Table 1]

Table 1: Procedural Time for successful cannulation between the two study groups

Parameters	Group US		Group PL		p< 0.001
	Mean	SD	Mean	SD	
Procedural time (in seconds)	30.1	32.4	88.1	91.4	

Number of Attempts: The mean number of attempts was significantly lower in the ultrasound group (1.2 ± 0.5) compared with the palpation group (1.5 ± 0.6; p=0.024). [Table 2 and 3]

Table 2: Number of attempts between study groups

Number of attempts	Group US		Group PL	
	N	%	N	%
1	41	80.4%	31	60.8%
2	9	17.6%	16	31.4%
3	1	2.0%	4	7.8%
Total	51	100.0%	51	100.0%

Table 3: Mean number of attempts in each group

Parameters	Group US		Group PL		p=0.024
	Mean	SD	Mean	SD	
Mean number of attempts	1.2	0.5	1.5	0.6	

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Number of Redirections: The ultrasound group required significantly fewer needle redirections than the palpation group (0.24 ± 0.51 vs. 0.76 ± 0.67; p=0.00. [Table 4]

Table 4: Number of redirections in the study groups

Number of redirections	Group US		Group PL		p value
	N	%	N	%	
1	8	15.7%	4	7.8%	<0.003*
2	2	3.9%	13	33.3%	
3	0	0.0%	3	5.9%	

Failure Rate and Change of Site: All participants were successfully cannulated within three attempts. No participant required a change of cannulation site.

Complications: Although complication rates were numerically lower in the ultrasound group, differences did not achieve statistical significance. [Table 5]

Table 5: Comparison of complications between study groups

Complications	Group US		Group PL		p value
	N	%	N	%	
Hematoma	10	19.6%	17	33.3%	0.116
Vasospasm	10	19.6%	10	19.6%	1
Posterior wall puncture	4	7.8%	10	19.6%	0.084

DISCUSSION

This randomized controlled trial demonstrated that ultrasound-guided radial artery cannulation significantly improves first-pass success rates and procedural efficiency compared with the traditional palpatory technique.

The first-attempt success rate of 80.4% observed in the ultrasound group was significantly higher than the 60.8% observed in the palpation group. These findings are consistent with the results reported by Shiver et al., who demonstrated first-pass success rates of 87% and 50% for ultrasound and palpation techniques respectively.[5]

Similar improvements have been reported by Kiberenge et al., Levin et al., and several meta-analyses evaluating ultrasound-guided arterial cannulation. [6-8,13,14]

A major advantage of ultrasound guidance is real-time visualization of the target artery and needle trajectory. This allows operators to identify vessel location, assess vessel patency, and avoid surrounding structures. Consequently, fewer attempts and needle manipulations are required, contributing to higher procedural success. Contemporary studies evaluating dynamic needle-tip positioning and advanced ultrasound-guidance systems have further demonstrated improvements in cannulation success and procedural accuracy.[9-11]

International guidelines on ultrasound-guided vascular access endorse these advantages and recommend ultrasound use whenever feasible.[4,16]

The reduction in procedure time observed in the present study is clinically important. Although ultrasound setup may initially appear time-consuming, improved first-pass success and reduced needle redirections ultimately shorten the overall duration of the procedure. The mean procedure time was reduced by approximately 58 seconds compared with the palpatory technique. Similar reductions in cannulation time have been reported in randomized trials and systematic reviews.[11-14]

The lower number of attempts and redirections observed in the ultrasound group is particularly relevant because repeated punctures are associated with patient discomfort and vascular trauma. Reduced needle manipulations may also explain the lower incidence of hematoma formation and posterior wall puncture observed in the ultrasound group. Studies evaluating dynamic needle-tip positioning techniques have similarly demonstrated fewer needle manipulations and improved first-pass success. [9-11]

Although differences in complication rates did not reach statistical significance, a clinically meaningful reduction was observed. The incidence of hematoma was reduced by nearly 40%, while posterior wall puncture occurred less frequently in the ultrasound group.

A larger sample size may have provided sufficient power to detect statistically significant differences. Similar observations have been reported in systematic reviews and meta-analyses evaluating complication profiles of ultrasound-guided arterial access. [13-14]

The findings of this study are supported by systematic reviews and meta-analyses. Tang et al. and Gu et al. reported improved first-pass success, reduced procedural time, fewer attempts, and lower hematoma rates with ultrasound-guided radial artery cannulation. [13,14]

More recent studies continue to demonstrate the benefits of ultrasound-guided radial artery cannulation and support its routine incorporation into perioperative and critical care practice. [12,15,16]

It was a single-center trial, operator blinding was not possible, long-term complications such as thrombosis and ischemia were not assessed being its limitations. A study involving larger sample size could pave the path for a generalized approach.

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CONCLUSION

Ultrasound-guided radial artery cannulation significantly improves first-attempt success rates and procedural efficiency compared with the traditional palpatory technique. It reduces procedure time, decreases the number of attempts and needle redirections, and may lower the incidence of cannulation-related complications.

Routine incorporation of ultrasound guidance into anesthesiology and critical care practice might prove beneficial, particularly in patients with anticipated difficult arterial access.

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