CLINICAL ANAESTHESIA

Prospective Randomized Study of Ultrasound-Guided In-Plane Versus Out-of-Plane Radial Artery Cannulation in Adult Cardiac Surgery Patients.

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Abstract

Background

With the more frequent use of ultrasound in medical practice, radial artery cannulation using ultrasound has proven to be better than the traditional landmark technique. Ultrasound-guided techniques reduce the risk of cannulation failure and complications like hematoma, arterial spasm, etc. Ultrasound is helpful in obesity, pediatric age group, and hemodynamically unstable patients with a feeble pulse. This study performed a comparison between in-plane and out-of-plane ultrasound-guided techniques for cannulation of the radial artery.

Methodology

This study was prospective randomized and interventional. The study involved adult patients scheduled to undergo cardiac surgery requiring arterial cannulation. Institutional ethics committee approval and consent was taken from the patients. A total of 128 patients were randomized into the in-plane and the out-of-plane ultrasound groups. In the operation room, radial artery cannulation was done under local anesthesia using a hockey stick ultrasound probe. The objective of the study was to compare the incidence of first-pass success rate, the number of attempts, number of redirections, cannulation completion time and incidence of complications in two groups.
Results

The demographic data was found to be comparable. The in-plane group had a higher incidence of first attempt success as compared to the out-of-plane group with a P value of 0.021. There was no statistically significant difference in other clinical outcomes.

Conclusion

The in-plane technique had a higher first-attempt success rate. Hence it should be considered for use in routine practice to improve patient care.

Keywords: Radial artery cannulation, Ultrasonography, in-plane technique, out-of-plane technique, cardiac surgery

Introduction

Arterial cannulation is a routinely done procedure in the operation theater as well as in intensive care units. The technique has been in use since the early 1700s and has undergone many modifications. It provides the clinician with vital information such as real-time arterial blood pressure measurements as well as easy access for blood sampling. In regular practice the palpation or landmark technique is used, and the radial artery is most often chosen, owing to its easy accessibility as compared to the ulnar artery, which has a deeper and more tortuous course. The superficial and deep palmar arches also provide collateral circulation in the event of a complication.

When considering critically ill patients, geriatric and pediatric populations, the landmark technique does not guarantee a successful first attempt at cannulation. The incidence of multiple attempts, and complications like hematoma, arterial spasm are high with traditional palpation technique. In such cases, the use of ultrasound can minimize the problems mentioned above.

Point-of-care ultrasound is a new term coined, that signifies the use of ultrasound at the bedside to aid with rapid diagnosis of various conditions and to help improve the accuracy of procedures that are performed. For visualization of superficial structures, that are required for cannulation, high-frequency probes (7 MHz) are preferred as they give good resolution. High-frequency probes, however, provide poor penetration. Low-frequency probes (<5 MHz) can be used to view deeper structures but provide poor resolution.

Literature does not state which technique is better among the different ultrasound guided techniques which are in practice today. Aim of this study is to compare the incidence of successful radial artery cannulation using ultrasound-guided in-plane versus out-of-plane technique.
Methodology

This was a prospective, single centre, randomized, interventional study. The study was started after obtaining permission from the Institutional Ethics Committee (IEC No: 902/2020) and registering with the clinical trial registry of India (CTRI/2021/07/034730). The study included 128 adult patients scheduled for elective cardiac surgery requiring arterial cannulation. Patients having Negative Allen’s test, atherosclerosis of vessels, ulnar artery damage or occlusion, cardiogenic shock, Raynaud’s disease, skin infection over insertion site, emergency cardiac surgeries, coagulation disorders, and peripheral vascular disease were excluded from the study. The participants were randomized into two groups, in-plane or out-of-plane ultrasound groups using computer-generated randomization. The participants were explained in detail about the study, the methodology, advantages, likely complications, and consent was taken.

In the operating room after attaching monitors and noting the base line vitals, the patient’s hand (preferably left hand) was positioned in dorsiflexion and fixed over a roll. The radial artery was then approached under strict asepsis using a 20 G catheter under local anesthesia (1 to 2 ml of plain lignocaine hydrochloride). A hockey stick linear ultrasound probe was used. The procedure was performed in all patients by the same anaesthesiologist taking part in the study, (who was well versed in both the techniques and had carried out more than 100 cannulations of the radial artery in adults using both in-plane and out-of-plane technique before the study). Data such as successful first pass radial artery cannulation, number of redirections, cannulation completion time, number of attempts to cannulate the artery, number of failed attempts, and occurrence of vascular complications like hematoma, arterial spasm, and posterior wall damage or puncture were recorded in both the techniques. A failed attempt was defined as unsuccessful cannulation after the third attempt. After a failed cannulation the randomization was broken, and technique was changed to ensure successful cannulation. The diameter of the radial artery in the antero-posterior axis and distance measured from skin to the anterior wall was also recorded. Radial artery canula was connected to the transducer for invasive arterial pressure monitoring. The patient was preoxygenated and induced with IV Propofol and IV Fentanyl in titrated doses. Paralysis was ensured with IV Vecuronium after confirming adequate mask ventilation. Once endotracheal intubation was complete patient was maintained on inhalation agent of choice.

The following observations were made during the study.

**Successful first-pass radial artery cannulation:** Successful arterial cannulation with a single skin prick without any redirection of the cannula.

**Number of redirections:** Redirection of cannula without removing it from the surface of the skin.

**Cannulation completion time:** Time taken for introduction of cannula through the skin to the placement of the radial artery catheter successfully.

**Total number of attempts** taken as total number of skin pricks.
Number of failed attempts: Failure to cannulate radial artery after third attempt.

Results
A total of 128 participants were included with 64 participants in either group.

The data was recorded in an Excel spreadsheet and analysed using the software, SPSS Statistics Version 23. The demographic data was compared using the independent t-test and categorical data was analysed using the chi-square test. A P value of <0.05 was labelled as significant.
As seen in Table 1, there was no statistical difference in gender, age, and blood pressure of participants in both groups and the parameters were comparable.

Table 2 represents the successful first pass, number of attempts and number of redirections taken to catheterize the artery in both groups.

Table 2. The successful first pass, number of attempts and number of redirections taken to catheterize the artery in both groups.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>In-plane group (n=64)</th>
<th>Out of plane group (n=64)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful first pass</td>
<td>47 (73.43%)</td>
<td>35 (54.68%)</td>
<td>0.021*</td>
</tr>
<tr>
<td>No. of attempts n (n%)</td>
<td>1 60 (93.75%)</td>
<td>54 (84.37%)</td>
<td>0.079*</td>
</tr>
<tr>
<td></td>
<td>2 3 (4.68%)</td>
<td>10 (15.62%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 0 (0%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 1 (1.56%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>No. of redirections n (n%)</td>
<td>0 47 (73.43%)</td>
<td>35 (54.68%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 4 (6.25%)</td>
<td>9 (14.06%)</td>
<td>0.060*</td>
</tr>
<tr>
<td></td>
<td>2 8 (12.50%)</td>
<td>17 (26.56%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 4 (6.25%)</td>
<td>3 (4.68%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 1 (1.56%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
</tbody>
</table>

* Chi-square test

Discussion

Arterial cannulation is an important procedure employed in many healthcare scenarios. It provides the physician with important information that helps improve patient care. The routinely used palpation technique has been shown to require multiple attempts as well as cause patient discomfort. In critically ill patients, geriatric, and paediatric population, especially, arterial cannulation becomes a challenge.

Ultrasound has been used as an important tool in vascular access and has been found to be of immense help. Though literature clearly states that use of ultrasound-guided techniques is better than the traditional
Table 3 Represents time taken for cannulation, arterial diameter, distance of artery from skin number of failed attempts and complications of procedure.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>In plane group</th>
<th>Out of plane</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannulation time (mean ± sd) (s)</td>
<td>21.9 ± 15.1</td>
<td>25.6 ± 14.8</td>
<td>0.15</td>
</tr>
<tr>
<td>Diameter of artery (mean ± sd) (mm)</td>
<td>2.30 ± 0.55</td>
<td>2.20 ± 0.40</td>
<td>0.27</td>
</tr>
<tr>
<td>distance from skin to anterior wall (mean ± sd) (mm)</td>
<td>2.67 ± 0.97</td>
<td>2.39 ± 0.82</td>
<td>0.08</td>
</tr>
<tr>
<td>No. failed attempt n (n%)</td>
<td>1(1.56 %)</td>
<td>0(0% )</td>
<td>0.31</td>
</tr>
<tr>
<td>Complications n(n%)</td>
<td>posterior wall puncture</td>
<td>6 (9.37 %)</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Arterial spasm/hematoma</td>
<td>2 (3.12 %)</td>
<td>0*</td>
</tr>
</tbody>
</table>

# Independent t test, *chi-square test

palpation technique, there is no clear conclusion reached on which ultrasound-guided technique is better.

A randomized controlled study was performed by Yeap YL, et al in a teaching institute where radial artery cannulations were done by trainees. The palpation technique was compared to radial artery cannulations done under ultrasound guidance. All arterial cannulations were performed by 3rd year resident anaesthesiologists. The study concluded that the USG method had fewer attempts, reduced incidence of cannula damage and higher success rate (96% vs 90%)⁶.

Berk et al. published an article in 2013, where they compared the long-axis in-plane (LA-IP) and the short-axis out-of-plane technique (SA-OOP). In study 108 patients who required radial artery cannulation before elective surgery were included. It was seen that the time taken for cannulation was reduced in the LA-IP group as compared to the SA-OOP group. Less number of attempts were required in SA-IP group. The short-axis group had more incidence of posterior wall puncture⁶.

Sethi et al. also compared two popularly used methods. On comparing short-axis and long-axis technique, they concluded that the difference between success rates of cannulation was not significant statically. Since the full needle length could be seen, complications were less in the long-axis technique⁷.

In 2020 Zhang et al. performed a meta-analysis on the utility of ultrasound for arterial catheterization in the paediatric population. Like studies conducted in adult population, the ultrasound assisted technique proved superior in increasing the success of cannula placement and brought down the number of attempts that were required. The occurrence of complications like hematoma were also significantly less in the ultrasound group⁸.

Anantasit et al. performed a study on critically ill paediatric population including 83 children who required more invasive monitoring. Once again ultrasound proved to be a valuable tool with lesser time and attempts required for cannulation. It was also noted that the complications like hand ischemia, haemorrhage, thrombosis, and hematoma was lesser in the ultrasound group⁹.

Kim et all performed a study in 256 elderly patients above the age of 65 years. A comparison was made between the dynamic
Ultrasound-guided in-plane Vs out-of-plane radial artery cannulation

needle tip positioning (DNTP) technique and palpation technique. The rate of successful first pass cannulations was 85.9% in DNTP vs 72.3% in palpation technique, which was statistically significant. The DNTP group also had better overall successful cannulation and lesser incidence of complications like hematoma formation\textsuperscript{10}.

This study compared the in-plane ultrasound guided technique and the out-of-plane technique. Sixty-four patients were included in each group and the rate of successful first pass was compared as the primary objective. Our study concluded that the in-plane technique had a higher successful first pass and the difference was statistically significant (P value= 0.021; 73.43% vs. 54.68% respectively). This outcome was similar to the trial carried out by Arora et al. that stated that the in-plane group had higher first pass success rate (P value=0.007; 85.7% vs. 57.1%).

In our study the number of attempts was analysed as a secondary objective. Sixty patients who were allocated to the in-plane group required only one attempt, whereas in the out-of-plane group successful cannulation could be achieved in a single attempt in 54 patients. Though clinically the in-plane technique proved to better, there was no statistical significance difference (P value= 0.079; 93.75% vs. 84.37% respectively).

On comparing the number of redirections between the in-plane and the out-of-plane group, though the in-plane group required a smaller number of redirections, the P value was not significant (P value=0.06).

The time taken for completion of cannulation the in-plane and out-of-plane group were compared and found to be similar. (P value =0.159; 21.9±15.1 s vs. 25.6±14.8 s respectively).

The occurrence of complications such puncture of the posterior wall, thrombosis and hematoma development were also similar in both the groups. Other clinical outcomes compared were the number of failed attempts and the number of cannulas damaged, which were also comparable in both groups.

Distance measured from skin to the anterior wall and the antero-posterior diameter of the radial artery as measured in the two techniques were compared and found to be similar.

The limitations of our study were that the arterial cannulations were performed in adult population between the age groups of 18 and 70 years. Hence the outcomes in paediatric and patients aged above 70 years were not assessed. The arterial cannulations were performed by a trained anaesthesiologist who was experienced in both techniques; therefore, it cannot be applied to trainees and junior anaesthesiologists. The study was performed on adult patients undergoing cardiac surgeries, patients posted for other procedures and critically ill patients were not enrolled in the study.

**Conclusion**

From this study, it is evident that utilizing the in-plane ultrasound-guided technique for radial artery cannulation significantly enhances the likelihood of achieving a successful first-pass cannulation. Therefore,
the in-plane ultrasound-guided technique should be prioritized over the out-of-plane technique to minimize multiple attempts.

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References