EDITORIAL

Ultrasound-guided Arterial Cannulation: What are We Missing and Where are We Headed?

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Arterial cannulations are routinely performed in Intensive Care Units (ICUs), operative settings, and catheterization labs for both diagnostic and therapeutic purposes.[1] The primary uses include continuous pulse assessment, arterial blood gas sampling, and monitoring the effects of vasopressor therapy. Of the various sites available for catheterization, the radial artery is most preferred due to its ease of access and insertion. This procedure can be performed either blindly using the traditional palpation method or with ultrasound assistance. However, blind radial arterial cannulations pose a higher risk of complications such as hematoma formation, failure to cannulate on the first attempt, multiple punctures, vasospasm, infection, pseudoaneurysm, and, in rare cases, permanent digital ischemia.[2]

The advent of point-of-care ultrasound has significantly improved the process of arterial cannulation by reducing the incidence of these complications.[3] Ultrasound guidance enhances the identification of the artery, the puncture site, the ease of cannulation, and the visualization of the guidewire. Despite its advantages, complications can still occur. These are influenced by patient-related factors such as obesity, edematous states, pediatric or elderly status, arterial diseases, and hypotensive conditions requiring vasopressors, as well as the operator's skill level.

Minimizing complications in arterial cannulation critically depends on achieving first-attempt success, as repeated attempts significantly increase the risk of complications and reduce the overall success rate. Although ultrasound guidance has improved first-attempt success rates, there is substantial variability in operator proficiency with ultrasound, leading to different success rates between experienced and less experienced practitioners.[4]

In this issue of the Indian Journal of Critical Care Medicine (IJCCM), Mishra et al.[5] present a systematic review and meta-analysis on the use of acoustic shadowing to aid ultrasound-guided arterial cannulation. The findings demonstrate a significant improvement in first-attempt success rates and a reduction in complications for radial artery catheterization using this technique. The method involves developing lines from a radiopaque object on ultrasound to guide needle advancement. Both single and double-developing line techniques are employed. In the single developing line method, the artery is localized by aligning the line through the artery, whereas in the double developing line method, the artery is positioned between two developing lines.[6] The incidence of failed first attempts decreased by approximately 53% (with variations from 66 to 34%) compared to unassisted ultrasound guidance. Additionally, there was a significant reduction in hematoma formation in the acoustic shadow intervention group.

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The strength of this systematic review lies in its comprehensive search and broad inclusion criteria, covering all age groups. The review included multiple databases such as PubMed, EMBASE, EMCARE, MEDLINE, The Cochrane Library, Google Scholar, ongoing trials, the WHO registry, and grey literature, employing an extensive and robust search strategy. After excluding 786 studies, the authors included six randomized controlled trials (RCTs), encompassing a total of 777 participants. Detailed demographic and intervention data were reported, and the overall risk of bias was low. The certainty of the effect was moderate for the first-attempt success rate but low for other outcomes. A sensitivity analysis excluding the pediatric population study found that the intervention's effect persisted with a similar magnitude.

While the results of the systematic review and meta-analysis appear convincing with good effect estimates, several concerns remain. First, all studies focused on radial artery cannulation, with none exploring the use of the technique in the femoral artery. While similar effects may be assumed for femoral artery cannulation, this is not certain. The efficacy of ultrasound-guided techniques compared to unassisted catheterization may be limited to smaller vessels and not necessarily applicable to larger or easily accessible femoral vessels. Secondly, three of the six studies originated from a single research group, showing increasing effect estimates across successive studies, possibly reflecting performance bias due to the group's growing expertise with the technique rather than the technique itself. Thirdly, the beneficial effect appears limited to first-attempt success and is not evident in subsequent attempts. The ultrasound-guided technique should ideally assist irrespective of the attempt number. The wider confidence interval precludes definitive conclusions for this outcome, failing to rule out the possibility of a beneficial effect. One plausible explanation could be the hematoma formation

and distortion of the artery lumen, potentially making the technique less effective during subsequent attempts. Fourthly, the authors reported considerable heterogeneity regarding the time to cannulation, that prevented them from drawing definitive conclusions.

Additionally, the literature identifies several potential concerns with this technique, including an increase in preparation time.[7–10] Specifically, setting up a probe with radiopaque strands can take additional minutes, potentially delaying cannulation, which could be critical in urgent situations. This delay is particularly concerning in emergency scenarios where rapid arterial access is essential for patient stabilization and management. Furthermore, the technique is particularly advantageous for a short-axis/out-of-plane approach to radial artery catheterization but is not suitable for a long-axis/in-plane approach. The short-axis/out-of-plane approach allows for better visualization of the artery and surrounding structures, facilitating more accurate needle placement. However, advanced users often utilize both approaches for successful cannulation, depending on the clinical context and specific patient anatomy. Moreover, the effectiveness of the developing line technique depends significantly on the diameter of the radiopaque strands. Studies have experimented with various materials, including metal wires and strands from surgical gauze. Metal wires may be too thin to effectively develop a clear line, potentially compromising the visualization of the artery. In contrast, radiopaque strands from surgical gauze, due to their larger diameter, are more effective in creating a distinct developing line, thereby enhancing the accuracy of needle guidance.

Both single and double-developing line methods have been investigated. The single developing line method is analogous to M-mode ultrasound, where a single line is used to localize the artery. While this method provides a significant improvement over traditional techniques, the double-developing line method has been reported to be more effective. The double-line method involves positioning the artery between two parallel radiopaque lines, which enhances the precision of needle placement and reduces the likelihood of complications such as arterial perforation or hematoma formation. This dual-line approach provides a more robust framework for guiding the needle, improving first-attempt success rates and overall procedural safety.

In summary, while the systematic review and meta-analysis provide promising evidence supporting the use of ultrasound guidance for radial artery cannulation, several critical issues need to be addressed. Future studies should expand the scope of the investigation to include femoral artery cannulation and other vascular sites to validate the generalizability of these findings. Additionally, efforts should be made to minimize performance bias by involving diverse research groups and standardizing training protocols. Further research is also needed to explore the reasons behind the limited efficacy in subsequent attempts and to better understand the factors contributing to heterogeneity in time to cannulation. Addressing these concerns will be essential for optimizing the use of ultrasound guidance in arterial cannulation and ensuring its broad applicability and effectiveness. Yet, the innovation is notably cost-effective and can be seamlessly integrated into routine ICU patient care. Its incorporation into training modules can further enhance the adaptability of this intervention.[11] The technique is equitable and versatile, with no associated adverse effects. With advancements in technology, this approach may eventually be integrated directly into ultrasound devices. Until then, this low-cost solution is adequate for current clinical needs.

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