Arterial insertion method: A new method for systematic evaluation of ultrasound-guided radial arterial catheterization

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Abstract
Introduction: Peripheral arterial catheter insertion is a common procedure for critically ill patients requiring frequent blood gas sampling and continuous blood pressure monitoring. There are clear advantages of ultrasound-guided arterial cannulation, which have shown to be more effective in reducing complications, time to successful cannulation, number of attempts, and overall first-time success rates. Evidence suggests that using palpation alone has a first-time success rate of less than 70% yet is still a widely performed technique. A systematic evaluation may be required to reduce variations in arterial catheterization practices.

Design: The arterial insertion method is a systematic evaluation to aid in arterial catheter insertion with ultrasound guidance, intended to improve the procedural approach. The process of arterial insertion method ensures appropriate choice of zone selection to optimize catheter longevity and performance in patients requiring arterial access. Moving the insertion site proximally 4 cm from the red zone into the green zone may reduce mechanical complications and preserve catheter performance and dwell time.

Conclusion: The standardization of ultrasound guidance in arterial catheterization promotes vessel health and patient safety through device and site optimization. The arterial insertion method systematic evaluation may be utilized to reduce variation in practice and promote the use of ultrasound as a standard for the insertion of radial arterial catheters.

Keywords
Radial artery, peripheral arterial catheterization, ultrasound vascular access, risk reduction, patient safety, intensive care

Introduction
Peripheral arterial catheter (PAC) insertion is a common procedure for critical care patients requiring frequent blood gas sampling and continuous blood pressure monitoring. These catheters are commonly inserted blind, using anatomical landmarks and a palpation insertion technique. According to the Centers for Disease Control and Prevention, the radial artery is the first choice for arterial catheterization due to its superficial location and the presence of redundant collateral blood supply to the hand by the ulnar artery in most patients.¹ Arterial catheter use in US intensive care units (ICUs) is 49.2% for patients undergoing mechanical ventilation and 51.7% for patients receiving vasopressors.²⁻⁴ Arterial catheter failure is frequently described as loss of catheter function, lack of blood return, loss of variation and quality in the arterial waveform, or catheter dislodgement.⁵⁻⁶ As an intravascular diagnostic device, arterial catheter waveform maintenance is essential, which consists of a saline or heparinized saline pressure bag to assist and maintain catheter patency. However, current evidence regarding the most appropriate infusate to maintain device patency and functionality found insufficient evidence to support the inclusion of heparin to maintain device patency.⁷

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The European Society of Anaesthesiology guidelines confirms clear advantages of ultrasound-guided arterial cannulation since it has been shown to be more effective in reducing complications, time to successful cannulation, number of attempts, and overall first-time success rates.8 Furthermore, evidence suggests that using palpation alone has a first-time success rate of less than 70%, yet is still a widely performed technique to cannulate the radial artery.9 Radial artery catheterization may be difficult in patients with obesity, atherosclerosis, or hematoma due to previous arterial punctures; weak pulse and low systolic blood pressure have correlated with a reduction in success rates.10 Failed puncture attempts increase the risk of hematoma formation, arterial spasm, intimal and nerve damage. Complications relating to failed punctures are frequently recognized after the procedure has been attempted. Such complications result in delays in treatment, as well as increased pain and distress from repeated attempts. The blind cannulation technique results in the position of the puncture site extremely close to the radial styloid process, or distal wrist crease, the greatest point of flexion (see Figure 1(a) and (b)). Areas of flexion contribute to the need for wrist stabilizers, which may add cost to the arterial catheterization procedure. Patient spontaneous wrist movements are also associated with an increased risk of radial artery catheter malfunction, dressing disruption, and infections.11 Peripheral vascular access devices are encouraged to reside outside of areas of flexion as these areas increase the rate of mechanical catheter failure, resulting in loss of arterial waveform.12

Current insertion techniques include the Seldinger technique (catheter over a guidewire) and the direct puncture method (catheter over the needle). Both techniques when performed without visualization may result in vessel transfixion. Transfixing the vessel may lead to complications associated with catheter dwell.10 When preparing the patient for arterial catheterization, the patient’s wrist is hyperextended, often with the use of a towel roll. This supports the 45° wrist angulation which promotes radial artery cannulation success.13 The towel roll technique positions the artery in an unnatural state; therefore, to preserve catheter function due to wrist hyperextension, an arm-board may be required. Mechanical failure considerations should include insertion location, catheter securement, dressing adherence, transducer tubing, and patients’ range of motion (ROM).14 There is clear evidence to support avoidance of device insertion in areas of flexion or motion for peripheral access–type catheters due to the risk of catheter loss, mechanical failure, and infection.15

Ultrasound-guided vascular catheterization has been shown to be superior than the blind insertion technique.8,10,16–20 Due to the limited insertion locations for arterial access, ultrasound should be considered to preserve arterial vessel health. While ultrasound use has gained a wider acceptance for venous access, it has been a slower adoption for arterial catheterization.20

The authors will identify, based on the available studies from the literature, a new method for a simple and reproducible systematic evaluation and a standardized ultrasound-guided approach for the cannulation of the radial artery in adult patients.

### Arterial insertion method

The arterial insertion method (AIM) is a new systematic approach designed to aid in arterial catheter insertion with ultrasound guidance, intended to optimize the procedural approach. This approach promotes identification of the ideal insertion zone (see Figure 2) for peripheral arterial catheterization with ultrasound guidance. Like the zone insertion method (ZIM)21 used for venous access, AIM outlines the segmented region of the radial artery to include depth, size, and zone.

While the palpable regions of the radial artery are relatively superficial, the proximity to underlying nerves, bone, and ligaments increases insertion-related complications,
device dysfunction, and patient discomfort. Unlike arterial catheters placed for short-term operating room use, arterial catheters for ICU patients require device reliability for several days to ensure adequate blood sampling and continuous blood pressure monitoring. The process of AIM ensures appropriate choice of zone selection to optimize catheter longevity and performance in patients requiring arterial access.

A 2018 systematic review and meta-analysis of 12 randomized control trials demonstrated an increase in first-time success rate with ultrasound compared to palpation-guided access. Compared with manual palpation, ultrasound-guided arterial catheterizations were associated with decreased failure rates by almost 50%. Authors determined that ultrasound guidance may reduce injury to nearby structures and decrease catheter-related infections through improved first-pass successes.

Kim et al. studied regions of the wrist comprising three distinct palpation locations that span 5 cm along the radial artery: Cun (Chon), Guan (Gwan), and Chi (Cheok). To determine the palpation locations, a practitioner places his or her middle finger on the prominent bone and sequentially lines up the index and ring fingers on the radial artery. Guan is located just below the middle finger, Cun below the index finger, and Chi beneath the ring finger (see Figure 3). The authors studied differences in the properties of the radial artery between Cun, Guan, Chi, and proximal artery segments, focusing on arterial vessel depth, diameter, and blood flow characteristics using ultrasound. These properties were compared at the three palpation locations and at three non-pulse-diagnostic locations (non-palpation locations) that are more proximal than Chi on the same radial artery and the left versus right arms. The colored AIM zones are modeled after Cun (red), Guan (yellow), and Chi (green). These zones highlight the importance of the use of ultrasound guidance when selecting a site within the non-pulse-diagnostic location (green zone represented by Chi, P1, P2, P3).

Taking inspiration from the ZIM, the AIM method may
have the advantage of encouraging the clinician to avoid areas of flexion (red and yellow zones) and to adopt a deeper and proximal cannulation site (green zone), furthermore affirming the use of ultrasound for radial artery catheterization.

This study Kim et al. found that arm posture affected the artery depths at Cun (red) and Guan (yellow); however, no dependence was found at Chi (green) or at the three non-palpable locations P1, P2, and P3 (green). This implied greater stability of the non-palpable locations of the radial artery, improving the location for insertion and securement of a radial arterial catheter. The authors' analysis revealed that the normalized artery depth differed significantly between Cun (red), Guan (yellow), and Chi (green) (left: \( p = .001 \); right: \( p < .0001 \)); however, no significant differences were observed among P1, P2, and P3 (see Figure 4). In contrast, the normalized artery diameter exhibited no significant differences between Cun, Guan, and Chi, but a significant difference was found among P1, P2, and P3 (left: \( p = .0002 \); right: \( p = .0032 \)).

A blind palpation technique often results in a catheter insertion within the described red and yellow zones. The arterial vessel is closest to the surface in the yellow zone. The use of ultrasound may be more difficult in the red and yellow zones due to the superficial vessel position. While the AIM approach is designed to move the insertion point to a more superior anatomical position, the vessel in this location is the deepest of the three zones and considered non-palpable (see Figure 5). For this reason, movement proximal into the green zone requires the use of ultrasound guidance for device insertion. More importantly, the use of ultrasound allows the clinician to perform device insertion in a region outside of flexion or ROM (red or yellow zones). Moving the insertion site proximally 4 cm from the red zone into the green zone may reduce mechanical complications and preserve catheter performance and dwell time (see Figure 5).

**Figure 4.** Diagram of the anatomical and hemodynamic characteristics at both arms. Courtesy of Kim et al.

**Limitations**

There are several limitations to this article; first, the zones are based upon adult patient research and do not specifically address pediatric patients; second, it is discussing the use of the radial artery only; third, it only describes the benefits of use with ultrasound as a technology, not identifying transverse or longitudinal planes of view.

**Conclusion**

The standardization of ultrasound guidance in arterial catheterization promotes vessel health and patient safety through device and site optimization. The AIM systematic evaluation may be utilized to reduce variation in practice and promote the use of ultrasound as a standard for the insertion of radial arterial catheters. This includes catheter performance, a reduction in mechanical failures, and enhanced dressing adherence and securement which may improve dwell time. Segmenting the forearm into the AIM zones for ultrasound-guided insertion may increase the reliability of hemodynamic monitoring parameters due to optimized arterial flow, improved vessel size, and superior device functionality. These elements alone should highlight the importance of thorough patient assessment and device management considerations that clinicians utilize prior to arterial catheterization.

This publication outlines a systematic approach for consideration during the use of ultrasound guidance for radial artery catheterization. This concept promotes avoidance of catheter insertion in areas of flexion (red and yellow zones). Furthermore, ultrasound-guided insertion in the green zone may reduce mechanical complications by minimizing area-related mechanical failures. The AIM is a simple, reproducible, systematic evaluation that may be utilized to reduce variation in practice and promote the use of ultrasound as a standard for the insertion of radial arterial catheters. Future research, with sufficient sample sizes,
is recommended to identify the benefits in critically ill patients requiring radial artery catheterization utilizing the AIM systematic evaluation.

**Declaration of conflicting interest**
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