American Journal of Emergency Medicine (2010) **28**, 343–347

ELSEVIER

The American Journal of Emergency Medicine

www.elsevier.com/locate/ajem

**Brief Report**

# Needle tip visualization during ultrasound-guided vascular access: short-axis vs long-axis approach

**Michael B. Stone MD[a,*], Cynthia Moon MD[a], Darrell Sutijono MD[a], Michael Blaivas MD[b]**

[a]*Department of Emergency Medicine, SUNY Downstate/Kings County Hospital Center, Brooklyn, NY 11203, USA*
[b]*Department of Emergency Medicine Northside Hospital Forsyth, Atlanta, GA 30041, USA*

Received 5 October 2008; revised 25 October 2008; accepted 20 November 2008

**Abstract**

**Objectives:** Ultrasound guidance for central venous catheterization improves success rates and decreases complications when compared to the landmark technique. Prior research has demonstrated that arterial and/or posterior vein wall puncture still occurs despite real-time ultrasound guidance. The inability to maintain visualization of the needle tip may contribute to these complications. This study aims to identify whether long-axis or short-axis approaches to ultrasound-guided vascular access afford improved visibility of the needle tip.

**Methods:** A prospective trial was conducted at a level I trauma center with an emergency medicine residency. Medical students and residents placed needles into vascular access tissue phantoms using long-axis and short-axis approaches. Ultrasound images obtained at the time of vessel puncture were then reviewed. Primary outcome measures were visibility of the needle tip at the time of puncture and total time to successful puncture of the vessel.

**Results:** All subjects were able to successfully obtain simulated blood from the tissue phantom. Mean time to puncture was 14.8 seconds in the long-axis group and 12.4 seconds in the short-axis group ($P$ = .48). Needle tip visibility at the time of vessel puncture was higher in the long-axis group (24/39, 62%) as opposed to the short-axis group (9/39, 23%) ($P$ = .01).

**Conclusions:** In a simulated vascular access model, the long-axis approach to ultrasound-guided vascular access was associated with improved visibility of the needle tip during vessel puncture. This approach may help decrease complications associated with ultrasound-guided central venous catheterization and should be prospectively evaluated in future studies.



## 1. Introduction

Physicians use ultrasound to facilitate needle placement for a wide variety of procedures, including (but not limited to) central and peripheral venous catheterization, arterial catheterization, regional nerve blocks, paracentesis, thoracentesis, lumbar puncture, pericardiocentesis, and arthrocentesis. Multiple studies have demonstrated an improved success rate and a decreased complication rate for ultrasound-guided vascular access as compared to the traditional landmark technique [1-3]. Complications using ultrasound

* Corresponding author. Tel.: +1 917 865 2551.
*E-mail address:* sunysono@gmail.com (M.B. Stone).

0735-6757/$ – see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.ajem.2008.11.022

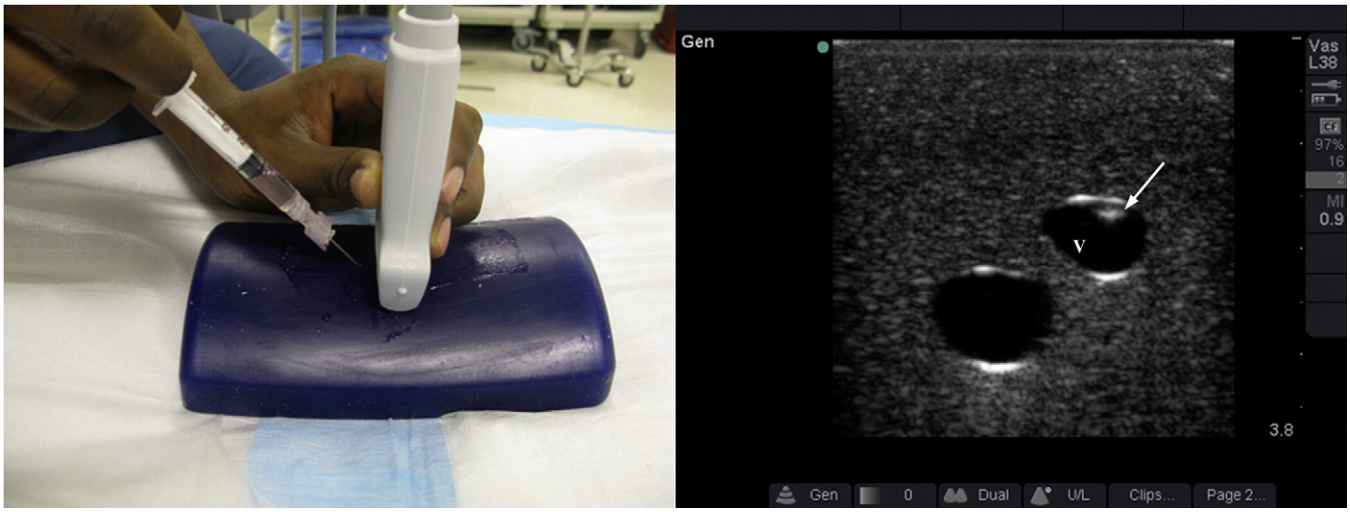


**Fig. 1** The needle is inserted perpendicular to the transducer (left image) and appears on the ultrasound screen (right image) as a dot (arrow) within the lumen of the vessel (v).

guidance for needle placement have been described [3,4], and lack of visualization of the needle tip during needle advancement may contribute to inadvertent puncture of vital anatomic structures and failed vascular access attempts.

Needle placement with ultrasound guidance can be performed using either a short-axis (out-of-plane) or a long-axis (in-plane) approach to visualize the needle as it is advanced toward the desired target. In the short-axis approach, the transducer is oriented transversely to the vessel, and the vessel appears as a circular anechoic structure. When the needle is inserted perpendicular to the transducer, it bisects the plane of imaging and therefore appears as a hyperechoic "dot" on the ultrasound screen (Fig. 1). In the long-axis approach, a longitudinal view of the vein is obtained, and the vein appears as a tubular anechoic structure. The needle is inserted parallel to the transducer's longest axis directly under the center of the transducer and therefore lies completely within the plane of imaging (Fig. 2).

A comparison of short-axis and long-axis approaches to ultrasound-guided vascular access by novice physicians on a tissue phantom demonstrated a decreased time to puncture using the short-axis approach [5]. Two previous studies comparing needle visibility using short-axis and long-axis approaches (and multiple different needles of various size, with and without image-enhancing properties) demonstrated superior needle visibility using the long-axis approach, but these studies were performed by analyzing static images obtained after needles were previously placed by experienced operators [6,7]. We hypothesize that the long-axis approach will afford improved visualization of the needle tip during simulated ultrasound-guided vascular access.

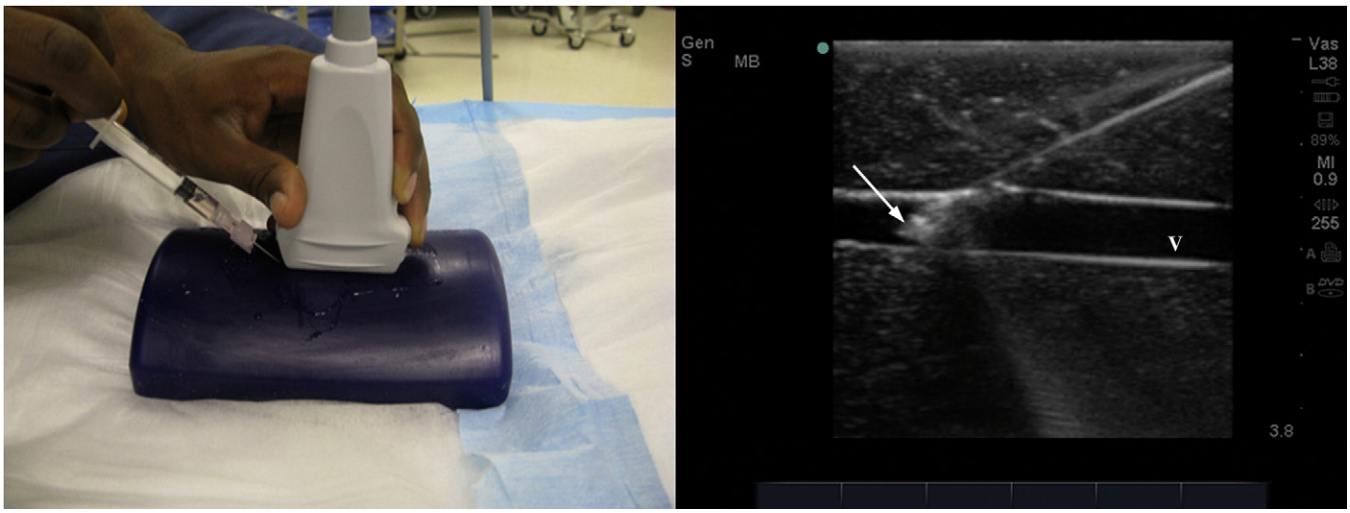


**Fig. 2** The needle is inserted parallel to the transducer (left image) and appears on the ultrasound screen (right image) as a line with the needle tip (arrow) within the lumen of the vessel (v).

## 2. Methods

### 2.1. Study design

This was a prospective, randomized study of novice operators using short-axis vs long-axis techniques for real-time ultrasound-guided vascular access on a tissue phantom. Institutional review board approval was obtained with a waiver of written informed consent.

### 2.2. Study setting and population

The study was conducted at a level I trauma center with an emergency medicine residency. The study population included senior medical students and first-year emergency medicine residents with little to no experience with ultrasound-guided vascular access (<5 ultrasound-guided vascular access procedures).

### 2.3. Study protocol

All participants were presented with a 20-minute didactic session on the proposed ultrasound-guided procedure included physics, machine operation, basic image adjustment, and example video clips of ultrasound-guided vascular access on a tissue phantom using both short-axis and long-axis approaches. Subjects did not receive hands-on practice before participation.

All subjects performed both long-axis and short-axis techniques, and the order in which they were performed was determined by a computer-generated random number list. Subjects were not allowed to observe other subjects while a session was being conducted.

During the study, an 18-gauge introducer needle on a 5-mL syringe was inserted into a curved block tissue phantom (Blue Phantom Inc, Bothell, Wash) under real-time ultrasound visualization using a 10-5 MHz linear transducer without compound imaging (Sonosite Micromaxx, Bothell, Wash). Time from first phantom tissue puncture to successful vessel puncture (as judged by a "flash" of simulated blood in the syringe) was measured, and the image was frozen and recorded at the time of initial flash, representing the ultrasound image viewed at the time of vessel puncture. Two investigators (MS and MB) independently reviewed these still images presented in random order.

### 2.4. Measures

The primary outcome measures were the time from first synthetic skin puncture until "flash," and the visibility of the needle tip on the ultrasound image at the time of vessel puncture. This image was frozen and saved for subsequent review. Additional measures include year of training, number of ultrasound-guided vascular access procedures previously performed, and overall preference of short-axis or long-axis approach.

### 2.5. Methods

For 80% power and .05 $\alpha$, the sample size necessary to detect a 33% difference in needle tip visibility was 39 subjects. A 2-tailed Fisher exact test was used to analyze needle tip visibility and a paired Student $t$ test was used to analyze time to "vein" puncture. A sample of still images obtained at the time of "flash" was interpreted by 2 of the primary investigators to determine interobserver agreement.

## 3. Results

Thirty-nine subjects participated in the study; 22 were third- and fourth-year medical students and 17 were emergency medicine interns. All subjects were able to successfully obtain simulated blood from the tissue phantom. Needle tip visibility at the time of vessel puncture was higher in the long-axis group: the needle tip was visible at the time of puncture in 24 (62%) of 39 long-axis attempts and in 9 (23%) of 39 short-axis attempts ($P$ = .01). There was no significant difference in time to vessel puncture in the long-axis and short-axis groups: mean time to puncture was 14.8 seconds in the long-axis group and 12.4 seconds in the short-axis group ($P$ = .48). There were no significant differences in performance among students and interns. Procedure order had no effect on needle tip visibility or time to puncture, and there was no difference in performance between participants who were assigned to short-axis vs long-axis for their initial attempts. Of 39 participants, 27 (69%) preferred the long-axis approach.

Two of the investigators (MS and MB) independently reviewed 34 still images obtained from attempts in both the short and long axes. Interobserver agreement was very good: $\kappa$ = 0.881 (95% confidence interval, 0.72-1.04).

## 4. Discussion

Ultrasound guidance for vascular access and other invasive procedures significantly improves procedural success and decreases complications. Only one prior study [5] has compared the short-axis vs long-axis approaches to vascular access and found that novice sonologists successfully completed the procedure in less time when using the short-axis approach. Our study results suggest that novice sonologists are able to obtain access in a much shorter time than previously reported, and that there is no statistically significant difference in time to access regardless of the approach used. Our study used a commercial tissue phantom (as opposed to a home-made tissue phantom) and a more

advanced ultrasound system with significantly higher spatial resolution: differences in time to access may be attributable to either the phantom or the ultrasound system.

Our results also suggest that the long-axis approach affords improved visualization of the needle tip at the time of puncture. This is not a surprising result to operators familiar with ultrasound-guided procedures because it is often difficult to maintain visualization of the needle tip when performing a procedure using the short axis. For instance, in regional nerve anesthesia under ultrasound guidance, the standard approach calls for visualization of the needle in its long axis to keep careful track of the needle tip [8,9]. It is commonly thought that this is only way possible to achieve the precision necessary to deliver anesthetic but avoid nerve damage.

There is reason to believe that ultrasound-guided vascular access using the short-axis approach may regularly lead to unsuspected needle penetration of sensitive structures. One study found that residents with some prior experience in ultrasound-guided vascular access regularly penetrated the posterior wall of the internal jugular vein on a life-sized torso vascular access mannequin [10]. Residents not only regularly penetrated the posterior vessel wall, losing track of the needle, but also cannulated the carotid artery in several instances. The authors did not evaluate the long-axis approach nor sought a reason for the frequent posterior wall penetrations. Our study offers one potential answer; the inability of novice sonologists to keep track of the needle tip in the short axis. This is consistent with a more recent study of emergency physicians' evaluation of needles that had been previously placed into vascular access tissue phantoms, wherein posterior vein wall penetration was identified more frequently in the long-axis view than in the short-axis view [11]. However, accidental penetration of the posterior wall of the vessel may occur due to other factors such as speed of needle insertion, angle of insertion, distance from needle entry to transducer, or other factors. Further studies are necessary to prospectively compare complication rates, particularly posterior venous wall penetration, using these 2 approaches to ultrasound-guided vascular access.

Importantly, additional approaches to vascular access exist; most notably an oblique approach [12] and a more dynamic approach in which the provider switches freely between long-axis and short-axis views to maximize visibility of the needle tip and accuracy of needle redirection. Although these alternate approaches merit investigation, they require additional dexterity and may not be easily adopted by novice sonologists. These techniques should be prospectively evaluated to allow for comparison with the more traditional long-axis and short-axis approaches.

We have previously reported a case of inadvertent carotid artery cannulation using ultrasound guidance with the short-axis approach [13], and there is evidence that carotid artery puncture occurs in 1.1% to 1.7% [3,4] of cases despite the use of ultrasound guidance. Improved visualization of the needle tip during procedural guidance may help reduce these complications and should be investigated in future studies. Most studies of ultrasound-guided vascular access have focused on the short-axis approach, which is commonly taught to novice sonologists. Our participants preferred using the long-axis and were able to visualize the needle tip more successfully using this approach. Although most ultrasound-guided vascular access research has focused on the internal jugular approach, it is important to mention that penetration of the posterior wall of the target vessel could also occur during the subclavian approach and could cause serious complications such as pneumothorax, hemothorax, and/or significant bleeding from a noncompressible vessel.

### 4.1. Limitations

Our study used an inanimate tissue phantom, and care must therefore be taken when extrapolating the results to live human subjects. Although not a perfect replica of human anatomy, this type of model offers a realistic simulation of needle movement and visualization, and is used by phlebotomists, nursing students, and medical students when learning vascular access procedures. Our results were obtained during a single session, and any potential changes in needle tip visualization or time required for vascular access that result from continued practice are unknown. It is striking that all medical students and interns enrolled were able to gain access on their first attempt. This 100% success rate exceeds previously reported rates of ultrasound-guided vascular access success in real patients [14], and similar results may or may not be obtained in vivo. Although unlikely that participants' performance would decline with subsequent practice, it is possible that needle tip visualization in short-axis and/or long-axis approaches might improve.

## 5. Conclusion

Using an inanimate tissue phantom, all participants were successful in their first attempt to puncture a simulated vessel using ultrasound guidance. There was no difference in time required for vascular access regardless of short-axis or long-axis techniques. Participants using the short-axis technique lost track of the needle tip at a significantly higher rate than in the long-axis. Inability to accurately keep track of the needle tip may be a contributing factor to procedural complications.

## References

[1] Miller AH, Roth BA, Mills TJ, et al. Ultrasound guidance versus the landmark technique for the placement of central venous catheters in the emergency department. Acad Emerg Med 2002;9:800-5.

[2] Milling TJ, Rose J, Briggs WM, et al. Randomized, controlled clinical trial of point-of-care limited ultrasonography assistance of central venous cannulation: The Third Sonography Outcomes Assessment Program (SOAP-3) Trial. Crit Care Med 2005;33:1764-9.

[3] Karakitsos D, Labropoulos N, De Groot E, et al. Real-time ultrasound-guided catheterisation of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. Crit Care 2006;10:R162.
[4] Denys BG, Uretsky BF, Reddy PS. Ultrasound-assisted cannulation of the internal jugular vein. A prospective comparison to the external landmark-guided technique. Circulation 1993;87(5):1557-62.
[5] Blaivas M, Brannan L. Short-axis versus long-axis approaches for teaching ultrasound-guided vascular access on a new inanimate model. Acad Emerg Med 2003;10:1307-11.
[6] Schafhalter-Zoppoth I, McCulloch CE, Gray AT. Ultrasound visibility of needles used for regional nerve block: an in vitro study. Reg Anesth Pain Med 2004;29:480-8.
[7] Culp WC, McCowan TC, Goertzen TC, et al. "Relative ultrasonographic echogenicity of standard, dimpled, and polymeric-coated needles. J Vasc Interv Radiol 2000;11:351-8.
[8] Stone MB, Price DD, Wang R. Ultrasound-guided supraclavicular block for the treatment of upper extremity fractures, dislocations, and abscesses in the ED. Am J Emerg Med 2007;25(4):472-5.
[9] Blaivas M, Lyon M. Ultrasound-guided interscalene block for shoulder dislocation reduction in the ED. Am J Emerg Med 2006;24(3):293-6.
[10] Blaivas M, Adhikari S, Lyon M. An unseen danger: frequency of posterior vessel wall penetration by needles during ultrasound guided internal jugular vein central line placement. Ann Emerg Med 2007;50: S68-9.
[11] Baty G, Polan D, Nichols WL. Emergency physicians more accurately identify the potentially critical, posterior vessel wall needle-tip location by using a long-axis orientation of the ultrasound transducer. Ann Emerg Med 2008;52:S127.
[12] Phelan M, Hagerty D. The oblique view: an alternative approach for ultrasound-guided central line placement. J Emerg Med 2008 Sep 29. [electronic publication ahead of print].
[13] Stone MB, Hern HG. Inadvertent carotid artery cannulation during ultrasound guided central venous catheterization. Ann Emerg Med 2007;49:720.
[14] Keyes LE, Frazee BW, Snoey ER. Ultrasound-guided brachial and basilic vein cannulation in emergency department patients with difficult intravenous access. Ann Emerg Med 1999;34(6):711-4.