

patients with a tracheotomy and may be associated with a higher infection rate than the subclavian. The femoral approach is typically avoided in all but the most emergent situations. Transpectoral axillary vein cannulation with ultrasound guidance is a novel option that might provide a solution to the multitude of challenges for central venous access [2–4]. Theoretically, this approach combines the benefits of minimizing infection rates and increasing patient safety by using a directly visualized thoracic approach. This procedure was introduced in the anesthesia community, and it has not been well studied in emergency medicine settings.

1.2. Importance

The use of ultrasound to guide cannulation of the axillary vein to establish central venous access is a relatively new and understudied technique. One aspect that has not been researched is whether a transverse or longitudinal orientation of the probe offers the best view of the vein. The transverse method shows the vein and artery in cross section. The drawback of this approach is that the operator is not able to keep the needle in sight the entire time and therefore must use a stepwise pattern to keep the needle tip in view. The transverse approach has been suggested as being superior for cannulation of peripheral IV lines. The longitudinal method enables the operator to visualize the needle, including its tip, in its entirety from entry into the skin until vessel puncture. [6] The best method for visualizing and cannulating the axillary vein has yet to be established.

1.3. Goals of this Investigation

In this study, we evaluated the transverse and longitudinal orientation of the ultrasound probe for axillary vein cannulation to determine if one method is preferable. We sought to compare the 2 techniques in regard to the proportion of successful vein cannulations on the first skin puncture, the number of needle redirections, the number of complications, and the time to successful cannulation.

2. Methods

2.1. Study design

This randomized controlled crossover trial was conducted between September 2010 and February 2011. Participating physicians used ultrasound (z.one *ultra sp* Ultrasound System, L8-3 Linear Array; Zonare Medical Systems, Mountain View, CA) to detect and cannulate the axillary vein of a torso phantom model (central venous access training model; Blue Phantom, Redmond, WA) using transverse and longitudinal orientations of the probe. Result parameters, that is, time to successful cannulation, number of skin punctures, number of needle redirections, and number of complications, were recorded on a predesigned data sheet. The study was approved by the institutional review board.

2.2. Study setting and selection of participants

This study was conducted at an inner-city, academic medical center with an emergency medicine residency and an ultrasound fellowship program. Emergency medicine residents in their post-graduate years 1 through 5 and attending physicians volunteered to participate. This approach created a pool of physicians with a range of ultrasound experience, from residents and attendings with almost no experience to fellowship-trained ultrasonographers with certification through the Registry for Diagnostic Medical Sonography.

2.3. Study protocol

Participants were scheduled for individual times to perform the study. Upon their arrival, they were asked to complete a questionnaire

that asked about their training in and experience with emergency vascular ultrasound. A portion of the questionnaire was also completed after the trial, to determine the participants' poststudy preference in regard to transducer orientation. The participants were then asked to view a 7-minute PowerPoint presentation, illustrating axillary vein anatomy and providing instruction on the use of longitudinal and transverse ultrasound views to guide cannulation for intravascular access. The PowerPoint presentation contained factual, unbiased information about each of the approaches and did not recommend one as preferred or superior. Participants had the opportunity to practice visualization and cannulation using a gel block vascular phantom until they felt comfortable with the procedure. When requested by the participants, the researchers provided instruction during the practice sessions. All researchers were careful to present any information in an unbiased and consistent manner by scripted interaction and to not interject their own personal preferences for one method over the other. Competency in establishing ultrasound-guided vascular access was defined by the ability to aspirate fluid from the phantom using the longitudinal and transverse views (at least one time each).

Participants were then given time to explore the anatomy of the torso vascular phantom with the ultrasound machine. The torso phantom is an anatomically correct bust (Fig. 1) that has veins and pulsatile arteries that contain different colors of fluid and a distinct hyperechoic line deep to the artery and vein. When requested by participants, the researchers answered questions and identified relevant anatomy. After the participants felt comfortable with the use of the ultrasound machine and the anatomy of the torso vascular phantom, they were randomized to begin with either the transverse or the longitudinal view for ultrasound-guided cannulation of the axillary vein. Participants were given a maximum of 10 minutes to cannulate the vein. After the procedure was completed, the researchers confirmed placement of the guidewire, and the participants were asked to repeat the cannulation using the other ultrasound view. A poststudy questionnaire assessing preferences for insertion technique was filled out after completion of both attempts.



Fig. 1. The torso phantom used in this study.

Table 1
Baseline characteristics of study participants

	Transverse first	Longitudinal first	Difference (%)
Experienced operators ^a	17/30 (57%)	15/27 (56%)	1
Attending operators	8/30 (27%)	14/27 (52%)	25
Prior preference			
Longitudinal	1/30 (3%)	0 (0%)	3
Transverse	26/30 (87%)	20/27 (74%)	
Combination	3/30 (10%)	7/27 (26%)	
Prior experience			
Greater with transverse ^b	28/30 (93%)	25/27 (93%)	0

^a Experienced operators had performed 50 or more prior ultrasound-guided IV line placements.

^b Two operators in each group had an equal number of attempts with both approaches.

2.4. Methods of measurement

The experience of each operator was documented, specifically his or her familiarity with using longitudinal and transverse views on the ultrasound probe to guide insertion of peripheral and central lines. Each participant's status as a resident or an attending was recorded. Study data were collected pertaining to time to successful cannulation, number of skin punctures, number of needle redirections, and number of complications (arterial puncture, lung puncture.) All procedures done on the torso vascular phantom were video recorded, with the participants' permission. These recordings were reviewed by the researchers within 24 hours; consensus of at least 2 of the researchers was required to confirm collected data. Poststudy preferences were assessed through a second questionnaire to assess whether there were changes in provider preference after completion of the study.

Care was taken to avoid potentially biasing participants toward one particular method. The PowerPoint presentation provided instruction on how to place a central line in a transverse or longitudinal fashion to establish a standard baseline for all participants. Neither the questionnaires nor the PowerPoint instruction recommended the longitudinal or transverse approach to central-line placement.

2.5. Primary data analysis

Our primary analysis was the comparison of the proportions of successful cannulations for the 2 approaches. We defined *success* as venous cannulation on the first skin puncture with no redirects and no complications. We calculated the confidence interval for the difference in proportions using a normal binomial approximation and the difference in means using the *t* distribution. We calculated *P* values using McNemar test for paired proportions and the paired *t* test for comparison of means. We chose our sample size to achieve 80% power to detect a 25% absolute difference between groups from an expected success rate of 50% (50% vs 25%), with significance of .05.

To determine whether the groups differed in important characteristics, we examined the prevalence of experienced operators, attendings, and those with a prior preference for or relative experience with one approach. Based on the distribution of responses in our data, we defined experienced operators as those indicating they had performed 50 or more ultrasound-guided IV line procedures. Because the randomization resulted in attendings doing relatively more trials with longitudinal approach first, we also analyzed our main outcome variable in subgroups stratified by attending vs resident status.

3. Results

3.1. Characteristics of study subjects

Fifty-seven emergency medicine residents and attendings were sequentially enrolled in and successfully completed the study. As Table 1 shows, the groups were fairly equal in most features, except prevalence of attending operators.

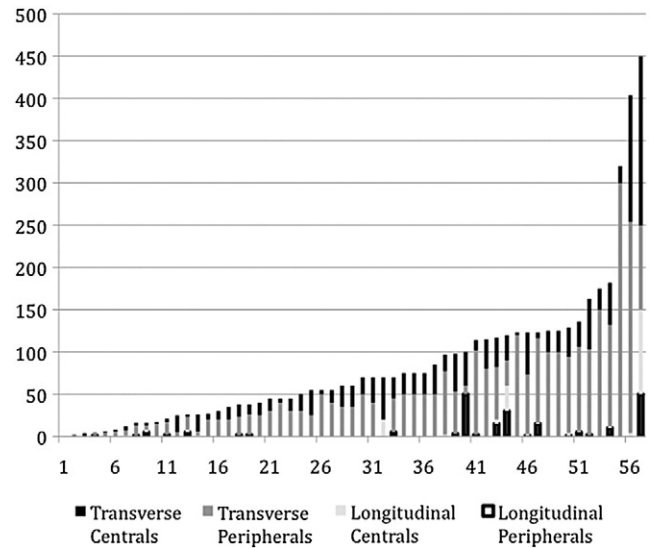


Fig. 2. Participants' experience.

The participants had a wide variety of experiences (Fig. 2). The 57 operators had a median experience of 85 previous ultrasounds (interquartile range, 26–120). Ninety-three percent of the participants had more experience with the transverse method before the training session.

4. Main results

In regard to our main outcome, the proportion with initial success was higher with the longitudinal than with the transverse orientation (Table 2). Subgroups of attendings (16/22 vs 7/22) and residents (23/35 vs 14/35) each had greater success with the longitudinal orientation. The longitudinal method was also associated with fewer redirections and shorter time to cannulation. The longitudinal technique showed a trend toward fewer skin punctures and a lower incidence of arterial puncture. Before the study, 1 (2%) of 47 participants indicating a preference for one technique over the other favored the longitudinal approach, compared with 32 (57%) of 56 favoring the longitudinal approach after the study.

5. Discussion

In this study, a longitudinal orientation of the ultrasound probe was superior to the transverse orientation for visualizing the axially vein. Not all comparisons were statistically significant, but all of them trended in favor of the longitudinal method. The longitudinal method was statistically superior in terms of successful placement on the first try without redirection of the needle or complications as well as number of redirections and time. These results were obtained from a population that was relatively inexperienced with the longitudinal approach.

Table 2
Trial comparison of transverse and longitudinal approaches

	Transverse (% or SD)	Longitudinal (% or SD)	Mean difference [95% CI], (<i>P</i> value)
Initial success	21/57 (37%)	39/57 (68%)	32% [12–51], (.001) ^a
Success in <10 min	54/57 (95%)	55/57 (96%)	2% [–8 to +11], (1.0) ^a
Redirections	2.1 (3.7)	0.4 (1.0)	1.8 [0.8–2.7], (.0002) ^b
Skin punctures	1.7 (1.5)	1.4 (1.0)	0.3 [–0.02 to +0.7], (.07) ^b
Arterial puncture	7/57 (12%)	2/57 (4%)	9% [–3 to +20], (.1) ^a
Time to IV access (s)	128 (88)	104 (52)	24 [3–45], (.02) ^{b,c}

CI, confidence interval.

^a McNemar test.

^b Paired *t* test.

^c Time (in seconds) based on 52 pairs in which operators succeeded by both approaches.

Previous research compared longitudinal and transverse imaging for the IJ vein and peripheral sites. For peripheral IV lines, the transverse approach is considered superior [5]. Investigators have selected the transverse approach for trials involving both peripheral and central venous access [7,8]. No study evaluating the preferred approach to the axillary vein was found in our literature review.

Central lines placed in the subclavian vein have yielded the lowest infection rate [9]. Unfortunately, this vein is difficult to visualize with ultrasound because it is located beneath the clavicle; therefore, subclavian central lines are generally placed by landmark methods. In contrast, the IJ vein is amenable to ultrasound guidance because of its unobstructed view. However, this vein is unavailable in a number of clinical scenarios such as in patients with neck infections, masses, burns, or trauma. In addition, the IJ vein site has a somewhat higher rate of infection in patients with a body mass index higher than 28.5 kg/m² and presents more complications in catheter site dressings and care [10]. The femoral approach, although frequently used in emergent situations, is considered a less desirable location for nonemergent vascular access because of its higher infection rate, its mechanical complication rate, and the inability to measure hemodynamic parameters [11,12]. Sandhu [3] and Bentley et al [13] presented the axillary vein as a reasonable option for central venous access.

The axillary vein courses from the teres major muscle in the arm to the first rib [3,13]. As it courses laterally, its depth increases, placing it closer to the lung pleura. For this reason, the longitudinal approach to ultrasound guidance may be better suited than the more common transverse approach. The advantage of the longitudinal approach is that it allows visualization of the entire length of the needle, including the tip, at all times. It also allows visualization of the guidewire as it is passed into the vein [14]. However, because the longitudinal approach is considered more challenging and few practitioners have experience with it, most practitioners continue to rely on the transverse approach.

The primary measure of cannulation on the first attempt with no redirections was achieved significantly more times using the longitudinal method, regardless of the order of attempts by inexperienced operators (data not presented). The longitudinal approach indeed fared better in all comparisons (except for plural punctures, which occurred in neither group), but only the differences in number of redirections and time were statistically significant. The clinical importance of a reduction in the number of redirections is that the risk of injury and damage to nearby structures are lessened. The time difference of 24 seconds might not have as large a clinical benefit for a procedure that, in some cases, took a full 10 minutes to complete. However, if the procedure can be performed in 1 to 3 minutes, which was the case for most of our study participants, 24 seconds becomes clinically relevant, especially from the patient's perspective.

The preference of the participants was also influenced by this study. Before the study, all participants had completed more cannulations using the transverse approach than the longitudinal approach. On the poststudy survey, most subjects indicated a preference for the longitudinal approach.

The study is limited by the use of a phantom. Although the phantom is constructed to be as anatomically accurate as possible, there are differences between the model and the human body. On the phantom, we attempted to look for pleural puncture. Although a pleural line was noted on the phantom, it is unclear how readily pleural puncture and subsequent pneumothorax would be appreci-

ated. Anatomy varies from human to human, and provider interaction with patients is different from that with the vascular phantom. The study would not have been possible using human participants because of the high number of central-line placements that would be required. The study was completed at a single center; therefore, the results may not apply to other settings. Specifically, the transverse approach has been favored and practiced at this facility by most physicians; other sites might have a preference for the longitudinal approach. Our findings may also have a sampling bias because we used volunteer participants, who may be more experienced, enthusiastic about, and comfortable using ultrasound. There is also the potential for recall bias of the participants on the initial questionnaire regarding the number of lines performed in the past. Because this study was nonblinded, the participants' responses on the posttrial portion of the questionnaire concerning preference for one approach could have been influenced by their perception of the investigators' expectations.

In conclusion, in this study using an anatomically correct phantom model, the longitudinal approach to the axillary vein during ultrasound-guided venous access was associated with greater first-attempt success, fewer needle redirections, and less time to IV access as compared with the transverse orientation. The axillary vein can be successfully cannulated after minimal teaching with good success.

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