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Is Long Axis View Superior to Short Axis View in Ultrasound-Guided Central Venous Catheterization?

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Abstract

Objective—To evaluate whether using long axis (LA) or short axis (SA) view during ultrasound-guided internal jugular (IJ) and subclavian (SC) central venous catheterization (CVC) results in fewer skin breaks, decreased time to cannulation, and fewer posterior wall penetrations (PWP).

Design—Prospective, randomized crossover study.

Setting—Urban emergency department with approximate annual census of 60,000.

Subjects—Emergency medicine resident physicians at the Denver Health Residency in Emergency Medicine, a PGY 1-4 training program.

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Study concept and design: Kendall
Acquisition of data: Vogel, Liao, Erickson, Theoret, Sanz, Kendall
Analysis and interpretation of data: Vogel, Liao, and Haukoos
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Interventions—Resident physicians blinded to the study hypothesis used ultrasound guidance to cannulate the IJ and SC of a human torso mannequin using the LA and SA views at each site.

Measurements—An ultrasound fellow recorded skin breaks, redirections, and time to cannulation. An experienced ultrasound fellow or attending used a convex 8–4 MHz transducer during cannulation to monitor the needle path and determine PWP. Generalized linear mixed models with a random subject effect were used to compare time to cannulation, number of skin breaks and redirections, and PWP of the LA and SA at each cannulation site.

Results—28 resident physicians participated: 8 PGY-1, 8 PGY-2, 5 PGY-3, and 7 PGY-4. The median [interquartile range (IQR)] number of total IJ central venous catheters placed was 27 (IQR 9-42) and SC was 6 (IQR 2-20) catheters. The median number of previous ultrasound-guided IJ catheters was 25 (IQR 9-40), and ultrasound-guided SC catheters was 3 (IQR 0-5). The LA view was associated with a significant decrease in the number of redirections at the IJ and SC sites, relative risk (RR) 0.4 (95% confidence interval [CI] 0.2-0.9), and RR 0.5 (95% CI 0.3-0.7), respectively. There was no significant difference in the number of skin breaks between the LA and SA at the SC and IJ sites. The LA view for SC was associated with decreased time to cannulation; there was no significant difference in time between the SA and LA views at the IJ site. The prevalence of PWP was: IJ SA 25%, IJ LA 21%, SC SA 64%, and SC LA 39%. The odds of PWP were significantly less in the SC LA, odds ratio 0.3 (95% CI 0.1-0.9).

Conclusions—The LA view for the IJ was more efficient than the SA view with fewer redirections. The LA view for SC CVC was also more efficient with decreased time to cannulation and fewer redirections. The LA approach to SC CVC is also associated with fewer PWP. Using the LA view for SC CVC and avoiding PWP may result in fewer central venous catheter-related complications.

Keywords

ultrasound; ultrasonography; central venous catheter; central venous access; subclavian vein; internal jugular vein

Introduction

Over 5 million central venous catheters are inserted annually in the United States.[1,2] Central venous access is an important tool in the resuscitation of critically ill patients; it facilitates essential hemodynamic monitoring, rapid volume resuscitation, and efficient delivery of medications and blood products.[3]

Ultrasound-guided central venous catheterization has become the standard of care in central venous access.[4,5] Using ultrasound guidance to place central venous catheters has been demonstrated to decrease the number of insertion attempts, time to cannulation, and complications of central venous catheterization.[6-15] When using ultrasound to place a central venous catheter, the physician has a choice of ways to use ultrasound to visualize the target vessel during catheter placement. In the short axis (SA) or cross-sectional view, the target vessel and its relationship to adjacent vessels (e.g. carotid) are visualized, but only a portion of the needle will be seen as it passes under the transducer and the needle tip may not be continuously visualized during catheter placement. In the long axis (LA) view, the length of the vessel and needle path including the tip can be continuously visualized during catheterization but the relationship of the target vessel to adjacent vessel(s) may be lost.[16,17]

Limited data exist to compare efficiency and outcomes of the LA and the SA views in ultrasound-guided catheterization of the internal jugular (IJ) and subclavian (SC). Chittoodan et al evaluated the LA and SA approach to IJ cannulation by experienced sonographers and found that SA afforded higher first pass success and fewer needle redirections.[17] Blaivas et al evaluated the SA and LA views in a model intended to simulate peripheral line access and found that novice ultrasound users secured peripheral vascular access more rapidly using a SA approach. The authors did not identify a significant difference between the LA and SA views in the number of skin breaks and needle redirections in the peripheral access model.[18]

Since the LA approach to cannulation affords continuous needle tip visualization, use of the LA approach has been advocated to limit potential complications associated with decreased needle tip visualization. Blaivas et al conducted a study of outcomes of SA IJ catheterization and found resident physicians inadvertently penetrated the posterior wall of the target vessel in the majority of cases.[19] Since vital structures such as the carotid artery and the lung parenchyma are posterior to these vascular access sites, avoiding posterior wall penetration (PWP) may reduce catheter-placement associated complications. To our knowledge, no studies have been conducted to compare efficiency and PWPs in the LA and SA views at both the SC and IJ venous access sites.

The objective of this study was to compare the skin breaks, time to cannulation, and PWP between the LA and SA view of the vessel for ultrasound-guided IJ and SC central venous catheterization. The primary hypothesis was that the LA view of the IJ and SC veins would result in more efficient central venous catheterization, with fewer skin breaks and less frequent PWPs as compared to the SA view.

Methods

Study Design and Setting

This was a randomized, prospective crossover study of a convenience sample of emergency medicine resident physicians at the Denver Health Medical Center in Denver, Colorado. The Denver Health Medical Center is a 477-bed, urban safety-net hospital with an annual adult census of approximately 60,000 visits. The Denver Health Residency in Emergency Medicine (DHREM), is an accredited four-year residency training program in emergency medicine, and is maintained and operated at the Denver Health Medical Center. Institutional review board approval was obtained for the study.

Study Population

DHREM emergency medicine resident physicians were eligible for inclusion in the study, and all were invited by electronic mail to participate. Participation in the study was voluntary and uncompensated. All emergency medicine resident physician participants were blinded to the study objectives and the data being collected for the purposes of the study.

The DHREM program provides a two-week ultrasound training program completed during the second year of residency training. This training program includes 3 hours of didactic instruction in ultrasound, 3 hours of hands-on supervised ultrasound training, 60 hours of scanning shifts, and 8 hours of video review of dynamic ultrasound images. Resident physicians who had not yet completed the ultrasound rotation prior to participation in the study were provided a 10-minute standardized instruction by an experienced ultrasound fellow or attending physician (C.L.E., M.M.L, or J.K) on how to obtain the LA and SA views at the IJ and SC sites on the phantom model used for the purposes of the study. The didactic instruction included observation of the instructor obtaining the SA view on the phantom model followed by rotation of the probe through 90° to provide LA visualization at the two cannulation sites, the SC and IJ veins. During the didactic instruction, the resident physician was afforded the opportunity to use the ultrasound probe to visualize the vessel in SA and LA at each site but was not allowed the opportunity to attempt vessel cannulation during the didactic session.

Data Collection

Resident physician participants completed a questionnaire prior to participation in the study. The questionnaire included the following self-reported data: year in training, estimated number of ultrasound-guided and landmark-guided IJ and SC catheterizations performed, estimated number of times LA view was used to place central venous catheters prior to study participation. The study participants rated perceived comfort with ultrasound-guided IJ and SC line placement on a 10-point Likert scale with 10 being the most comfortable.

Resident physician participants were asked to cannulate the IJ and SC veins of a human torso mannequin (Blue Phantom, Kirkland, WA) using the LA and SA views at each site. Each resident physician performed cannulation of the LA and SA at both the SC and IJ sites; a total of four cannulations completed for purposes of the study. The order in which cannulation was performed at each of the access sites was determined by a computer-generated random number list. The resident physicians used a 6 cc syringe and a 20 gauge needle from a central venous catheterization kit to cannulate the vessels of the human torso mannequin. Successful cannulation of the IJ and SC vessel was defined as aspiration of red fluid from the respective veins of the mannequin intended to simulate cannulation of the vessels in a live patient. Study participants were not allowed to observe each other during the individual sessions conducted.

Data on time to cannulation, number of needle redirections and skin penetrations, and whether PWP occurred during cannulation were recorded. An emergency medicine ultrasound fellow (J.T. or G.E.S.) observed the resident physician to record number of skin breaks defined as number of skin punctures, redirections defined as changes in the direction of the needle after insertion without removing it from the skin, and time to cannulation defined as time from skin break to successful vessel cannulation denoted by withdrawal of colored fluid intended to simulate venous blood. A second individual, an experienced ultrasound fellow or attending physician (C.L.E., M.M.L, or J.K.) with ≥ 2 years of emergency ultrasound experience and ≥ 100 ultrasound-guided central venous catheter placements used a convex endocavitary 8–4 MHz transducer during the cannulation to monitor the needle path and to determine whether PWP occurred during the procedure. This probe was placed in a position to enable the physician observer to visualize the posterior wall of the target vessel of the human torso mannequin without interfering with the resident physician's transducer or the resident physician's ability to successfully cannulate the target vessel. The observers recording information about the cannulation and the PWPs were not blinded to the study objectives.

Each resident physician participant was assigned a unique study identification number for the purposes of the study. All data were recorded using this unique study number, and no identifying information was collected from the resident physician participants.

Outcome Measures

The outcome measures for the study included: time to cannulation, number of skin breaks and redirections, and PWP during ultrasound-guided cannulation of the IJ and SC venous access sites using the LA and SA.

Data Management and Statistical Analyses

Data were recorded in an electronic spreadsheet (Microsoft Excel, Microsoft Corporation, Redmond, WA). The electronic file was then transferred into native SAS format using translational software (dfPower DBMS copy, DataFlux Corporation, Cary, NC). Descriptive statistics were calculated on the study participants and their clinical experience and comfort with ultrasound-guided central venous catheterization. All analyses were performed using SAS Version 9.3 (SAS Institute, Inc., Cary, NC). Continuous data are reported as medians with interquartile ranges (IQRs) and categorical data are reported as percentages with 95% confidence intervals (CIs).

Generalized linear mixed models were utilized to compare time to cannulation, number of skin breaks and redirections, and PWP of the LA and SA views at each cannulation site, IJ and SC. The distributions assumed in the generalized linear mixed models were log normal for time, negative binomial for number of skin breaks and redirections, and a binomial distribution for PWP. Because each study participant had varying level of experience and performed the LA and SA at the IJ and SC sites, a random subject effect was included in the model. The outcomes were modeled as a linear function of the two views, LA and SA, and included covariates for year in training, estimated number of central lines performed, and perceived comfort with ultrasound procedure at that cannulation site. Automated variable selection methods were not used to select variables for inclusion in either model. Instead we performed complete model analysis with variables being included based upon our *a priori* knowledge of known or hypothesized relationships between resident physician characteristics and outcomes in central venous catheterization. We assessed for collinearity using Pearsons correlation. There was significant collinearity between the number of ultrasound-guided lines performed and year in training in the IJ line placement. Given this, we did not include the number of ultrasound-guided lines previously performed at location site in the model for IJ line placement. We evaluated for period effects that may show a learning curve over the four successive cannulations. We also evaluated whether there were sequence effects present based on the randomly assigned order in which the four cannulations were performed.

Results

During the study period, 55 resident physicians (14 PGY-1, 14 PGY-2, 13-PGY3, and 14-PGY-4) were contacted regarding potential participation in the study. A total of 28 resident physicians participated: 8 PGY-1, 8 PGY-2, 5 PGY-3, and 7 PGY-4 resident physicians. Two resident physicians were unable to successfully cannulate the SC vein using the SA approach after 5 minutes. These two incomplete SA SC attempts were excluded from the analysis of the SC SA attempts.

The catheter placement experience of the resident physician participants in the study is shown in Table 1. The median comfort level with placement of ultrasound-guided IJ and SC catheters by study participants were 8 (IQR 7-9) and 4 (IQR 1-5), respectively, on a 10-point Likert scale with a score of 10 reflecting the highest level of comfort. The resident physicians had more experience with the SA approach to ultrasound guided central venous catheterization, and their experience with the LA approach at both cannulation sites was limited (Table 1). The outcomes of internal jugular and subclavian cannulation for the study are described in Table 2. The comparison between LA and SA for skin breaks and redirections is described in Table 3. The LA approach was associated with a significant decrease in the number of redirections at both the IJ and SC sites. There was no significant difference in the number of skin breaks between the LA and SA at the IJ and SC catheterization sites.

The median time to cannulation and absolute difference between the two views at each access site is demonstrated in Table 4. The SA view for SC was associated with significantly decreased time to cannulation. The adjusted hierarchical model completed to evaluate time to cannulation was consistent with these data and demonstrated the same direction and magnitude of difference between the SA and LA views at each access site.

The rate of PWP in each of the respective views at the two sites was as follows: IJ SA 25%, IJ LA 21%, SC SA 64%, and SC LA 39%. The odds of PWP were significantly less in the LA view at the SC site, odds ratio 0.3 (95% CI 0.1-0.9). The association between view type at each access site and PWP is outlined in Table 5.

The period effect over the four successive cannulations performed was statistically significant for number of skin breaks and redirections and time to cannulation. There was no statistically significant period effect for posterior wall penetration. There were no statistically significant differences in the sequence effects, or order in which the cannulations were performed, by the study participants.

Discussion

The objective of this study was to evaluate the efficiency and PWP rate in the LA and SA views during ultrasound-guided catheterization at the IJ and SC venous access sites. Our results demonstrate that the LA view at the SC site is more efficient with fewer redirections and decreased time to cannulation as well as fewer PWP. The LA view for the IJ is also associated with fewer redirections than the SA view.

To our knowledge, our study is the first of its kind to evaluate outcomes of the LA and SA views at both the IJ and SC sites. One study has compared the SA and LA approach to IJ central venous catheterization. In the study, Chitoodan et al compared outcomes of the SA and LA approach to ultrasound-guided placement of right IJ catheters in patients undergoing cardiac surgery. Patients were randomized to LA or SA approach, and each cannulation was performed by anesthetists with experience with >50 ultrasound-guided IJ cannulations. The investigators found that the first pass success rate was higher ($p<0.006$) and fewer needle passes ($p<0.004$) were necessary in the SA group as compared to the LA group. The authors acknowledged that the anesthetists who participated in the study had less experience with the LA approach to cannulation as compared to the SA approach.[17]

Several investigators have advocated for the LA approach to cannulation of the basilic, cephalic, and axillary veins. The authors of these investigations indicate that the LA approach offers the unique advantage of continuous visualization of the needle and improved visualization of deeper vessels. [20-22] Stone et al found that the LA approach to peripheral venous access afforded increased visibility of the needle tip at the time of vessel puncture as compared to the SA approach.[21] The LA view offers the advantage of real-time visualization of the tip of the needle[22] and visualization of the anatomic structure of the target vessel[24] which can be particularly beneficial in cases of anomalous anatomy. In our study, we found a decreased number of redirections using the LA approach at both the SC and IJ sites, and this may be due to the advantages afforded by continuous visualization of the needle tip in the LA thereby necessitating fewer redirections.

Although the SA approach to IJ catheterization allows visualization of the IJ and its relationship with the carotid, unless the ultrasound operator uses a proper triangulation technique in the SA to visualize the needle, the needle shaft can be mistaken for the needle tip.[16] In these circumstances, with the needle tip outside the view, the operator may inadvertently enter the carotid[14] or structures posterior to the target vessel such as the lung. Due to the difficulties associated with continuous visualization of the needle tip in the SA, the ultrasound operator may not realize he or she has punctured the posterior wall of the target vessel.

Blaivas et al conducted a prospective randomized blinded study of resident physicians, and found that in the SA approach to the IJ, inadvertent PWP occurred in the majority of catheterization attempts and the ultrasound operator was unaware of this outcome. The authors of the study suggested that ultrasound operators be particularly cautious about the location of the needle tip when visualizing the vessel in the SA or cross-sectional approach. Blaivas and his colleagues outlined several advantages of the LA approach to vessel cannulation, including continuous visualization of the needle and tip along with the theoretical advantage of not having inadvertent PWP and resultant damage to the structures posterior to the target vessel.[19] This is especially important since the carotid may lie immediately posterior to the IJ[19] and the lung parenchyma is posterior to the SC access site. Resnick et al also recommend using the LA to confirm both entry of the needle and angiocatheter into the vessel as well as to assess the length of the catheter within the vessel to ensure appropriate placement and reduce the potential risk of dislodgement.[20]

The LA approach to vessel cannulation affords unique advantages, but maintaining the needle in the plane of the ultrasound beam may be challenging, especially for novice ultrasound operators. Shofer and his colleagues propose a step-wise approach to maintaining needle visualization in the plane of the ultrasound beam. The steps include obtaining the LA view, stabilizing the transducer with the nondominant hand, placing the tip of the needle in the middle of the transducer footprint, inserting the needle, applying the transducer to visualize the needle tip, and advancing the needle to successful cannulation. Shofer and his colleagues indicate that using this approach, the LA approach has become the preferred method of visualization of vessels for central venous catheterization at their institution.[25]

While this study demonstrated that LA approach resulted in fewer redirections at both the IJ and SC sites, and decreased time to cannulation and PWP at the SC site, there are some limitations with the LA view. The LA approach may not be feasible in certain anatomic types, such as short neck, which does not allow use of the probe in the vertical orientation necessary for the LA view. At the IJ site, the LA view does not afford continuous visualization of the anatomic relationship between the carotid and the IJ. Given this, for the IJ catheterization the ultrasound operator could begin with the SA approach to correctly identify the vessel which is the IJ. The ultrasound operator can then rotate the probe to the LA view to facilitate cannulation of the IJ. It may be more difficult for a novice ultrasound user to maintain the probe in the appropriate position to maintain the needle in plane for the LA visualization. However, if ultrasound education during residency training and at conferences included instruction in the advantages and use of LA for central venous catheterization, users may become more facile with use of the LA view.

Studies such as this one help to determine ways to potentially improve the safety of central venous catheterization, and offer the opportunity to establish goals for physician ultrasound training and proficiency during central venous catheterization. A physician with skills in the different approaches to ultrasound-guided catheterization will have a breadth of experience upon which they can rely in various patient presentations to facilitate efficient and safe central venous catheterization in the critically ill.

In this study, resident physicians were asked to cannulate the IJ and SC in a human torso mannequin (Blue Phantom, Kirkland, WA). While this study was not conducted on patients, the torso model used offers the most realistic simulation of cannulation of the IJ and SC vessels available without using live patients. We believe the simulated experience of catheterization on a mannequin offers insight into the best approach for successful vessel cannulation without posterior wall penetration. Future studies on live patients to evaluate the LA and SA approach to cannulation are indicated to confirm the applicability of our findings in the clinical setting.

This study was conducted at a four-year emergency medicine residency program, and a convenience sample of resident physicians was enrolled. It is possible that the resident physicians who agreed to participate may have been more facile or experienced with ultrasound-guided line placement which could have resulted in selection bias in this study. Since the DHREM has a structured ultrasound educational program, and ultrasound-guided central venous catheterization is standard of care at the medical facilities at which the residents are trained, we believe it is likely that resident participants and nonparticipants would have a similar ultrasound skill set. Due to the amount of training provided to the resident physicians at DHREM, they may have been more facile with securing and maintaining the LA view which may have impacted the study results. Future investigations with a broad range of resident participants from more than one residency training program are indicated to validate the findings of this study.

The resident physician participants were observed by an ultrasound fellow to record number of needle redirections, skin punctures, and time to cannulation, and by an experienced ultrasound fellow or attending to record occurrences of PWP. These fellow and attending observers were not blinded to the hypotheses of the study. This lack of blinding may have led to unconscious bias in reporting the results of the two view types at the IJ and SC sites, thereby impacting the results of our study.

Our study investigated successful cannulation of the vessel. We did not evaluate placement of a catheter into the venous access sites we investigated. Therefore, we cannot draw conclusions regarding whether using the LA approach may result in difficulty placing a catheter due to placement of the needle tip close to the lateral wall during catheter placement. Since the LA approach allows continuous visualization of the needle tip, we do not believe this to be a likely occurrence. However, further investigations are indicated to determine whether LA approach is associated with any difficulties with central venous catheter placement.

An additional limitation of this project is the use of a torso model mannequin for the study. Although resident physicians were instructed to approach cannulation of the vessel of the torso model as if it were a live patient, it is possible that the resident physicians may have assessed the risk of injury to the mannequin to be minimal and may have approached cannulation differently than in a live patient. This may have resulted in more aggressive cannulation attempts thereby decreasing time to cannulation. We believe the torso model used offers the most realistic simulation of placement of a central catheter in patients that is available without using live patients.

As the resident physician participants worked with the mannequin in each of the successive cannulation attempts, they may have gained additional experience with the mannequin which may have impacted the results of the four successive cannulation attempt measures. We did randomize the order in which the different views were used for cannulation, and we also incorporated a subject effect variable in the generalized linear mixed models to help control for individual subject effects in our analysis.

Conclusions

No difference was observed in PWP and time to cannulation between SA and LA approaches to the IJ. More PWP and longer time to cannulation were observed for SA approach to the SC and more redirections using the SA for IJ and SC. Use of the LA view for SC central venous catheterization may result in fewer central venous catheter-related complications such as pneumothorax.

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Table 1

Study participant internal jugular and subclavian catheter placement experience.

	IJ Catheter		SC Catheter	
	Median	(IQR)	Median	(IQR)
Total central venous catheters (CVC) placed				
All resident physicians	27	(9 – 42)	6	(2 – 20)
PGY-1	6	(5 – 8)	1	(0 – 2)
PGY-2	26	(21 – 29)	6	(4 – 13)
PGY-3	50	(35 – 51)	18	(17 – 18)
PGY-4	55	(35 – 75)	35	(25 – 45)
Number of US-guided CVC placed				
All resident physicians	25	(9 – 40)	3	(0 – 5)
PGY-1	6	(5 – 8)	0	(0 – 0)
PGY-2	25	(20 – 28)	0	(0 – 4)
PGY-3	50	(35 – 50)	12	(1 – 12)
PGY-4	53	(30 – 75)	5	(4 – 5)
Number of US-guided CVC in LA view				
All resident physicians	0	(0 – 4)	0	(0 – 0)
PGY-1	0	(0 – 0)	0	(0 – 0)
PGY-2	1	(1 – 2)	0	(0 – 0)
PGY-3	0	(0 – 5)	0	(0 – 0)
PGY-4	5	(2 – 5)	0	(0 – 1)
Self-reported comfort with US-guided CVC				
All resident physicians	8	(7 – 9)	4	(1 – 5)
PGY-1	5	(4 – 6)	1	(1 – 2)
PGY-2	8	(8 – 9)	4	(3 – 5)
PGY-3	9	(8 – 9)	5	(4 – 5)
PGY-4	10	(9 – 10)	5	(5 – 5)

Abbreviations: central venous catheter, CVC; IJ, internal jugular; IQR, interquartile range; LA, long axis; PGY, post-graduate year; SC, subclavian; US, ultrasound.

Table 2

Outcomes for internal jugular and subclavian cannulation.

	IJ Catheter				SC Catheter			
	Short Axis		Long Axis		Short Axis		Long Axis	
	Median	(IQR)	Median	(IQR)	Median	(IQR)	Median	(IQR)
Number of skin breaks								
All resident physicians	1	(1 – 1)	1	(1 – 1)	2	(1 – 3)	1	(1 – 2)
PGY-1	1	(1 – 2)	2	(1 – 2)	3	(1 – 4)	1	(1 – 2)
PGY-2	1	(1 – 2)	1	(1 – 1)	2	(1 – 3)	1	(1 – 2)
PGY-3	1	(1 – 1)	1	(1 – 1)	1	(1 – 2)	1	(1 – 1)
PGY-4	1	(1 – 1)	1	(1 – 1)	1	(1 – 2)	1	(1 – 1)
Number of redirections								
All resident physicians	1	(0 – 3)	0	(0 – 2)	5	(2 – 8)	2	(0 – 3)
PGY-1	2	(0 – 4)	2	(0 – 3)	6	(5 – 11)	2	(0 – 3)
PGY-2	1	(1 – 4)	0	(0 – 2)	5	(2 – 7)	2	(1 – 6)
PGY-3	1	(0 – 1)	0	(0 – 1)	4	(1 – 8)	2	(1 – 3)
PGY-4	1	(0 – 2)	0	(0 – 1)	4	(1 – 6)	2	(0 – 3)
Number of PWPs								
All resident physicians	0	(0 – 0)	0	(0 – 1)	2	(0 – 3)	0	(0 – 2)
PGY-1	0	(0 – 1)	1	(0 – 1)	3	(1 – 7)	1	(0 – 2)
PGY-2	0	(0 – 1)	0	(0 – 1)	2	(1 – 5)	0	(0 – 2)
PGY-3	0	(0 – 0)	0	(0 – 0)	0	(0 – 2)	0	(0 – 1)
PGY-4	0	(0 – 0)	0	(0 – 0)	2	(0 – 3)	0	(0 – 0)
Time to cannulation								
All resident physicians	15	(8 – 26)	10	(4 – 25)	66	(27 – 66)	19	(11 – 57)
PGY-1	26	(17 – 37)	22	(17 – 44)	105	(39 – 258)	27	(12 – 57)
PGY-2	18	(8 – 60)	9	(6 – 31)	71	(33 – 219)	28	(12 – 85)
PGY-3	10	(7 – 11)	5	(4 – 8)	45	(32 – 65)	16	(7 – 18)
PGY-4	9	(3 – 18)	4	(3 – 11)	45	(17 – 84)	16	(10 – 24)

Abbreviations: IJ, internal jugular; IQR, interquartile range; LA, long axis; PGY, post-graduate year; SC, subclavian; US, ultrasound.

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Table 3

Adjusted associations between approach types and the outcomes, skin breaks and redirections, by cannulation site as referenced to the short axis.

	Long Axis	
Variable	**Relative Risk**	**(95% CI)**
Internal Jugular§		
Skin breaks	0.8	(0.5 – 1.4)
Redirections	0.4	(0.2 – 0.9)
Subclavian‡		
Skin breaks	1.7	(0.9 – 3.2)
Redirections	0.5	(0.3 – 0.7)

§Each IJ model was adjusted for year in training, estimated total number of internal jugular (IJ) lines placed, and perceived comfort with IJ US-guided central line placement.

‡Each subclavian (SC) model was adjusted for: year in training, estimated number of SC lines placed, estimated number of US-guided SC lines placed, and perceived comfort with US-guided SC central line placement.

Table 4

Time to cannulation by access site.

	Short Axis		Long Axis		Absolute Difference†	
Variable	**Median Time (sec)**	**(IQR)**	**Median Time (sec)**	**(IQR)**	**Difference**	**(95% CI)**
Internal Jugular	14.5	(8.0 – 25.5)	9.5	(4.0 – 24.5)	-3	(-9, 3)
Subclavian	66.0	(27.0 – 95.0)	19.0	(11.0 – 57.0)	-27	(-58, -7)

Abbreviations: CI, confidence interval; IQR, interquartile range; sec, seconds.

†Wilcoxon signed rank test was used to compare paired median values, and Wilcoxon rank sum test was used to compare independent median values. Nonparametric point estimates and confidence intervals were estimated using the *cendif* and *centile* functions of Stata for paired and independent comparisons, respectively. The calculation of median differences using these methods may differ slightly from the value obtained from simple subtraction of group medians.

Table 5

Associations Between Cannulation Type and Posterior Wall Penetration as Referenced to the Short Axis.†

	Posterior Wall Penetration	
Variable	**Odds Ratio**	**(95% CI)**
Internal Jugular		
Long axis	1.7	(0.4, 7.6)
Subclavian		
Long axis	0.3	(0.1, 0.9)

†Adjusted for year in training, total lines placed, self-reported comfort with ultrasound guided subclavian, and number of ultrasound-guided subclavian lines placed.

Abbreviations: confidence interval, CI.