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Diagnostic accuracy of point-of-care ultrasound for catheter-related thrombosis in children

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Abstract

Background—Compared with consultative US performed by the radiology department, point-of-care US performed by non-radiology physicians can accurately diagnose deep venous thrombosis in adults.

Objective—In preparation for a multicenter randomized controlled trial, we determined the accuracy of point-of-care US in diagnosing central venous catheter-related thrombosis in critically ill children.

Materials and methods—Children <18 years old with a central venous catheter who were admitted to the intensive care unit were enrolled. Consultative and point-of-care compression ultrasounds with Doppler were done on the vein where the catheter was inserted within 24 h after insertion. Repeat US was obtained within 24 h of removal of the catheter. All images were centrally, blindly and independently adjudicated for thrombosis by a team of pediatric radiologists. Chance-corrected agreement between readings was calculated.

Results—From 84 children, 152 pairs of consultative and point-of-care ultrasounds were analyzed. A total of 38 (25.0%) consultative and 17 (11.2%) point-of-care ultrasounds were positive for thrombosis. The chance-corrected agreement between consultative and point-of-care ultrasounds was 0.17 (standard error: 0.07; $P=0.008$). With consultative US as a reference, the sensitivity of point-of-care US was 28.1% (95% confidence interval: 13.7%–46.7%) with a specificity of 91.8% (95% confidence interval: 84.4%–96.4%). A catheter in the subclavian vein

was associated with discordant readings (adjusted odds ratio: 4.00; 95% confidence interval: 1.45–13.94).

Conclusion—Point-of-care US, when performed by non-radiology physicians and centrally adjudicated by pediatric radiologists in the setting of a multicenter randomized controlled trial, may not accurately diagnose catheter-related thrombosis in critically ill children.

Keywords

Central venous catheter; Children; Intensive care unit; Point-of-care ultrasound; Ultrasound; Venous thromboembolism

Introduction

Ultrasonography is the imaging modality of choice for deep venous thrombosis (DVT) [1]. In critically ill children, the presence of a central venous catheter (CVC) is the most important risk factor for DVT [2]. In contrast to venography, which is the gold standard for diagnosing DVT, US can be done at bedside, which alleviates the need to transport critically ill children outside of the intensive care unit (ICU) [1, 3]. Consultative US performed by the radiology department, however, may be a limited resource because it requires sonographers who may not always be present during nights and weekends. The potentially limited availability of consultative US, along with the potential high resource utilization that can tax the hospital's system, may limit the conduct of randomized controlled trials of thromboprophylaxis in children [3].

Non-radiology physicians are increasingly using point-of-care US to diagnose diseases in critically ill patients. Point-of-care US provides a rapid and accurate method of diagnosing DVT in adults in the ICU [4, 5]. Compared with consultative ultrasound or venography, point-of-care US has an average sensitivity of 96.1% and specificity of 96.8% in detecting DVT in the proximal lower extremities [6]. Because these studies are confined to the femoral veins of adults, usually without a CVC, and adults are bigger than children, it is unclear whether point-of-care US can also be used to accurately diagnose CVC-related DVT in the upper and lower extremities of children [4, 6]. In preparation for a multicenter randomized control trial of thromboprophylaxis in critically ill children in which all US images will be adjudicated centrally, we determined the accuracy of centrally adjudicated point-of-care US in diagnosing CVC-related DVT confirmed by consultative US in critically ill children.

Materials and methods

Study design

We recently completed a prospective cohort study that determined the performance of biomarkers in predicting CVC-related DVT in critically ill children [7]. In this ancillary study to the prospective cohort study, we report the diagnostic accuracy of point-of-care US. The prospective cohort study, which was conducted from October 2012 to November 2013, enrolled consecutive children admitted to the pediatric ICUs at Yale-New Haven Children's

Hospital and Maria Fareri Children's Hospital. The institutional review boards of each institution approved the studies and required written parental permission.

Study subjects

Children <18 years old with a non-tunneled CVC inserted within the previous 24 h were eligible. Excluded were children with documented thromboembolic event within the past 3 months, as well as those expected to receive anticoagulants, on comfort measures only or scheduled for discharge from the ICU on the day of screening.

Study procedures

As part of the protocol of the prospective cohort study, consultative and point-of-care ultrasounds were performed on the day of enrollment (entry US), which was within a day after insertion of the CVC, on the central vein where the CVC was inserted to identify pre-existing DVT. Both ultrasounds were performed within 24 h of each other. Consultative and point-of-care ultrasounds were then repeated (exit US) within 24 h of removal of the CVC or earlier upon the child's discharge from the ICU, at 28 days after insertion of the CVC (even if the CVC had not been removed by that time and the child remained in the ICU), when CVC-related DVT was suspected clinically or when the child was unlikely to survive for the next 24 h. The veins were scanned proximal and distal to the site of insertion, which is where CVC-related DVT usually starts to develop [8]. Gray-scale images of the veins were acquired in the transverse and longitudinal planes every 2 cm or less. Transverse images were acquired with and without venous compression, and longitudinal images with and without color Doppler. For subclavian veins, images were acquired without compression only. The personnel who performed the consultative and point-of-care ultrasounds had discretion on the use of spectral Doppler, on the use of color Doppler on transverse images, and on image annotation with arrows and calipers. Images were archived for central adjudication. The personnel who performed the consultative and point-of-care ultrasounds were blinded to the findings from the other ultrasounds.

Registered diagnostic medical sonographers performed the consultative US using Philips® iU22® Ultrasound Imaging Platform (Philips Medical Systems, Bothell, WA) with 7–15 MHz linear transducers. Members of the research teams performed the point-of-care US. In Yale-New Haven Children's Hospital, the team was composed of a physician research coordinator, a pediatric critical care fellow and a board-certified pediatric critical care physician while the team in Maria Fareri Children's Hospital was composed of two board-certified pediatric critical care physicians. All members of the teams had approximately 2 years of experience in using point-of-care US to diagnose CVC-related DVT [8]. The pediatric critical care physicians had additional experience with POC ultrasound in inserting CVCs. The teams in Yale-New Haven Children's Hospital and Maria Fareri Children's Hospital used the M-Turbo® and S Series™ SonoSite ultrasound machines (SonoSite, Inc., Bothell, WA), respectively, with 6–13 MHz linear transducers.

Prior to the start of the study, the lead pediatric radiologist who had approximately 10 years of post-fellowship experience in diagnosing DVT by ultrasonography provided training to all members of the research teams on the use of point-of-care US and proper imaging of the

veins to detect DVT. The training session included 1 hour of didactic and hands on instructions focusing on the image-acquisition aspects of ultrasound scanning, including Doppler. In addition, the teams were provided information on the sonographic characteristics of a DVT. Another hour of return demonstration was spent during training to confirm proper technique for adequate image acquisition. The lead pediatric radiologist provided feedback regarding the quality of the images and additional training, as needed, during the study.

Upon completion of the study, blindly and independently, two pediatric radiologists, one from each institution, provided the initial readings for all US images. Consultative US images were read first; at least 1 month after, point-of-care US images were read. A third pediatric radiologist blindly arbitrated discordant readings and provided the final reading. Each of the radiologists had approximately 10 years of post-fellowship experience in diagnosing DVT by ultrasonography. Ultrasound images were classified as positive or negative for DVT, or unevaluable. CVC-related DVT was defined as presence of at least 2 of the following: intravenous echoic material, inability to compress the vein and abnormal Doppler pattern [8, 9]. Images in which at least two of these could not be evaluated were considered unevaluable.

Statistical analysis

Demographic characteristics were presented as count (percentage) or median (interquartile range [IQR]). Characteristics of unevaluable images were compared with those of evaluable images using chi-square, Fisher exact or Mann-Whitney U tests, as appropriate.

Concordance between the final readings of the paired consultative and point-of-care US images, and between the initial readings for the consultative and point-of-care US images were determined using crude and chance-corrected agreement (κ coefficient) adjusted for correlation between entry and exit ultrasounds [10]. Crude agreement was defined as the proportion of concordant readings between the paired images adjusted for correlation. Unevaluable images were considered negative for DVT in the primary analysis. Based on the frequency of CVC-related DVT in children of 18%, unevaluable images would likely be negative [11]. In the secondary sensitivity analyses, unevaluable images were considered positive for DVT or were excluded. Using only the evaluable images, we determined the sensitivity, specificity, positive predictive value and negative predictive value of point-of-care US in diagnosing CVC-related DVT with consultative US as reference.

We used multilevel logistic regression to identify predictors of discordant readings between the paired consultative and point-of-care US images. Based on review of the literature and technical plausibility, we decided a priori to include the level of training of the personnel who did the point-of-care US (i.e. board certified pediatric critical care physician vs. others), age of the child, z-score of the child's weight for age, site of insertion and size of the CVC, and presence of the CVC during US as fixed effects parameters [12, 13]. We used the z-score instead of the actual weight to control for variations in weight related to age [14]. ICU and individual child were entered as random effects parameters to account for clustering within ICUs and repeated imaging per child, respectively [15]. A similar model was used to identify predictors of unevaluable images. To minimize overfitting, we only included the

level of training of the personnel who did the point-of-care US, age of the child, site of insertion of the CVC and presence of the CVC during the US as fixed effects parameters with ICU and individual child as random effects parameters. The magnitude of association of the fixed effects parameters was expressed as odds ratios (OR) with 95% confidence intervals (CI). The variability accounted for by the random effects parameters was expressed as variance with 95% CI.

All statistical analyses were conducted using Stata 13 (StataCorp, College Station, TX). A 2-sided *P*-value <0.05 was considered statistically significant.

Results

Description of children and US images

A total of 84 of 85 children in the prospective cohort study participated in this ancillary study. The median age was 3 years (IQR: 0.3–11.7 years) while the median z-score of weight for age was −0.2 (IQR: −1.6–0) (Table 1). The median size of the CVCs was 5 Fr (IQR: 4–5 Fr) and most were inserted in the right side ($n=54$, 64.3%). CVCs were inserted in the femoral vein in 38 (45.2%) children, in the internal jugular vein in 31 (36.9%) children and in the subclavian vein in 15 (17.9%) children. A total of 163 consultative and 156 point-of-care ultrasounds were performed with 152 pairs analyzed. Of the pairs, 82 (54.0%) were done at study entry with the CVC in place. CVC was in place in 15 (21.4%) of 70 ultrasounds done at study exit. Board-certified pediatric critical care physicians performed the majority of point-of-care ultrasounds ($n=96$, 63.2%).

All consultative and 123 (80.9%) point-of-care ultrasounds were evaluable. The unevaluable images had poor quality that limited the visualization of the vein (Figs. 1 and 2). In the unadjusted analysis, unevaluable images were more likely than the evaluable images to have been done in Yale-New Haven Children's Hospital, by a non-board certified pediatric critical care physician, from a female child and possibly from a CVC inserted in the subclavian vein (Table 1).

Agreement between consultative and point-of-care ultrasounds

A total of 38 (25.0%) consultative and 17 (11.2%) point-of-care US images were positive for CVC-related DVT (Figs. 3 and 4 and Table 2). None of the children received anticoagulation nor was CVC removed in between the paired consultative and point-of-care ultrasounds. A total of 5 (13.2%) children with DVT on consultative US had signs of inflammation in the ipsilateral limb and another 5 (13.2%) had dysfunction of the CVC, i.e. inability to draw blood or infuse fluids through the CVC. The rest were asymptomatic.

There were 54 (35.5%) discordant final readings between the paired consultative and point-of-care US images (Fig. 5 and Table 2). In the primary analysis, when unevaluable images were considered negative for DVT, crude agreement was 0.76 with κ coefficient of 0.17 (standard error [SE]: 0.07; $P=0.008$). When the unevaluable images were considered positive, crude agreement was 0.69 and κ coefficient was 0.16 (SE: 0.08; $P=0.02$). Crude agreement was 0.75 and κ coefficient was 0.16 (SE: 0.08; $P=0.02$) when unevaluable images were excluded. Excluding unevaluable images, the sensitivity, specificity, positive

predictive value and negative predictive value of point-of-care US were 28.1%, 91.8%, 52.9% and 79.5%, respectively (Table 3). Point-of-care US had the best performance in the femoral vein (sensitivity of 29.4%, specificity: 93.6%) and worst in the subclavian vein (sensitivity: 0%, specificity: 83.3%).

Crude agreement and κ coefficient between initial readings of the consultative US images were 0.92 and 0.77 (SE: 0.08; $P<0.001$), respectively, while those for point-of-care US images when the unevaluable images were considered negative were 0.85 and 0.22 (SE: 0.07; $P<0.001$), respectively. When the unevaluable images were considered positive, crude agreement for the point-of-care US was 0.82 and κ coefficient was 0.51 (SE: 0.08; $P<0.001$). Excluding the unevaluable images, crude agreement was 0.85 and κ coefficient was 0.23 (SE: 0.08; $P=0.003$).

Predictors of discordant readings and unevaluable US images

After adjusting for physician-, subject- and CVC-related factors, CVC inserted in the subclavian vein was the only fixed effects parameter associated with discordant readings between consultative and point-of-care US images (OR: 4.00; 95% CI: 1.15–13.94) (Fig. 6). There was some variability among children (variance: 0.47; 95% CI: 0.02–12.68), but none between ICUs (variance: 0; 95% CI: 0–0), in discordant readings after accounting for the fixed effects parameters. None of the fixed effects parameters was associated with unevaluable images (Fig. 6). Unevaluable images were variable between ICUs (variance: 3.84; 95% CI: 0.26–57.56) and among children (variance: 6.88; 95% CI: 1.20–39.34).

Discussion

In this ancillary study to a prospective cohort study, point-of-care US had slight agreement with consultative US in diagnosing CVC-related DVT in critically ill children (κ coefficient of 0.16–0.17) [16]. With consultative US as reference, point-of-care US, when evaluable, was highly specific (91.8%) in diagnosing DVT. A CVC in the subclavian vein was associated with discordant readings (adjusted OR: 4.00; 95% CI: 1.45–13.94). Despite the potential advantages of using point-of-care US, our study does not support the use of centrally adjudicated point-of-care US performed by non-radiology physicians to diagnose CVC-related DVT in critically ill children in the setting of a multicenter RCT.

The role of point-of-care US in diagnosing CVC-related DVT has not been investigated before. There are no prior studies comparing consultative and point-of-care US specifically in patients with CVC or in the upper extremity veins. Therefore, it is unclear whether the κ coefficient of 0.16–0.17 in our study is typical. The concordance between consultative and point-of-care US is also reflected in the latter's diagnostic accuracy. In our study, with consultative US as reference, point-of-care US has an overall sensitivity of 28.1% and specificity of 91.8%, and a sensitivity of 29.4% and specificity of 93.6% in the femoral vein. In critically ill adults, the sensitivity of point-of-care US in diagnosing DVT in the lower extremities, with consultative US or venography as reference, ranged from 78% to 100% with specificity ranging from 96% to 100% [4–6]. In contrast to our study, in the studies in adults, non-radiology physicians who performed the point-of-care US also interpreted the

images. DVT seems easier to diagnose in the femoral vs. subclavian veins and without a CVC [1, 12].

Differences in the US machines likely contributed to our findings. While they may provide adequate images for many purposes, machines used in the ICU setting generally have inferior image quality compared to machines used for consultative examinations. In addition, scanning techniques to improve the quality of the images including the DVT, which sonographers gain from extensive training and experience, may not have been optimized with the point-of-care US machines. It would be interesting to determine whether differences between the consultative and point-of-care US were due to limitations of the machines or scanning issues.

Our 2-h training and the research teams' prior experience with point-of-care US may not have been sufficient, particularly because we also required Doppler. While some studies provided longer training, non-radiology physicians trained from 10 min to 2 h demonstrated sensitivity and specificity of nearly 100% in detecting DVT in the femoral veins in adults with point-of-care US [5, 17, 18]. In contrast to other studies, we trained our teams primarily on the image-acquisition aspects of scanning, and less on the diagnosis of DVT, because we plan to have a central adjudication of DVT in our multicenter randomized control trial [4–6].

In our study, CVC inserted in the subclavian vein was associated with discordant readings between consultative and point-of-care ultrasounds. Point-of-care US was least sensitive and least specific in the subclavian vein. This is not unexpected because of the difficulty in imaging and inability to compress the subclavian vein even in the absence of DVT [1, 12]. We had to demonstrate the presence of the two remaining sonographic criteria, i.e. intravenous echoic material and abnormal Doppler pattern, to diagnose DVT in the subclavian vein in our study.

We determined the agreement between readings of the consultative US in preparation for a multicenter randomized control trial. The κ coefficient of 0.77 is substantial but suboptimal because it is below the κ coefficient of 0.80 typically needed to robustly ascertain the outcome in a randomized control trial [16]. In studies preparatory to a multicenter randomized control trial of thromboprophylaxis in critically ill adults, the concordance between readings using consultative US ranged from 0.29 to 0.71 in the upper extremity veins to 1.00 in the lower extremity veins [19, 20]. We will conduct calibration studies in our multicenter randomized control trial to increase the κ coefficient to at least 0.80 [19].

Our motivation for this ancillary study was to identify an alternative method of diagnosing CVC-related DVT for a multicenter randomized control trial. However, some of our findings may have clinical implications, particularly in institutions where consultative US is not readily available. When images are evaluable, point-of-care US was highly specific suggesting that it may be used to rule in CVC-related DVT, especially when the clinical suspicion of DVT is high [6, 21]. In children with signs of DVT on physical examination, a sonographic definition of DVT that is less stringent than what we used may be considered. A consultative US would be preferred if the point-of-care US is negative for DVT or unevaluable, or to screen for CVC-related DVT in asymptomatic children [21]. This

approach should probably be limited to CVCs in the femoral or internal jugular vein. Studies are needed to test this approach.

Our study has limitations. The radiologists in our study relied solely on the archived images without any discussions from those who performed the point-of-care or the consultative US. This is in complete contrast to routine clinical practice. However, in the context of a multicenter randomized control trial, such discussions may introduce bias in the adjudication process and, thus, were not done in our study. Use of cine clips might have provided unbiased information in lieu of real time scanning. We did not obtain cine clips based on the design of prior studies [19, 20]. Although venography is the gold standard for diagnosing DVT, we used consultative US as reference because venography is uncommonly used in children [1]. Consultative and point-of-care US were performed within 24 h of each other. Although unlikely, DVT might have developed between examinations resulting in discordant readings. We did not find associations between the child's age, age-adjusted weight or presence of the CVC during the US and discordant readings or unevaluable images, likely due to our sample size. We did not have preliminary data to conduct a formal sample size calculation. A larger multicenter study should be performed to confirm our results. Prior to this study, we suggest that each center should be required to show certain standards. Lastly, our results may not be generalized to patients who are not critically ill, do not have CVC or have other types of CVC.

Conclusion

Point-of-view US, when performed by non-radiology physicians and centrally adjudicated by pediatric radiologists in the setting of a multicenter randomized control trial, may not accurately diagnose CVC-related DVT in critically ill children. It only has slight agreement with consultative US. When evaluable, point-of-care US performed by non-radiology physicians achieved high specificity when compared with images obtained by consultative US and when centrally adjudicated by pediatric radiologists.

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Fig. 1.

A 6-day-old girl with shock. Unevaluable images on point-of-care US (**a–c**) and normal scan on consultative US (**d–e**). The right supraclavicular region was scanned. Only 3 images were obtained on point-of-care US because of poor sonographic access (small child). The images were considered unevaluable because the pediatric radiologists could not identify with confidence any vein in the images despite arrow notation on (**b**) and presence of color Doppler box on (**c**). **d–e** Longitudinal images of the right supraclavicular region depicting the medial (**d**) and mid (**e**) portions of the right subclavian vein with normal flow on color and spectral Doppler

Fig. 2.

An 8-year-old girl with acute liver failure. Unevaluable images on point-of-care US. **a** Composite transverse point-of-care US image at the level of the right common femoral vein (arrows) with (right) and without (left) color Doppler. The images were considered unevaluable because the pediatric radiologists could not identify the vein with confidence despite arrow notations on both images and presence of color Doppler box on the image on the right. Bandages caused a veil-like shadow artifact along the center of both images (arrowheads), which likely contributed to obscuration of the vein. **b** The corresponding consultative US images were read as normal. A slightly more lateral approach during scanning brought the bandage artifact (arrowhead) out of the region of interest, allowing depiction of a normal vein

Fig. 3.

An 11-month-old boy with acute respiratory failure. Normal scans on both consultative (**a** and **b**) and point-of-care (**c** and **d**) US. **a** Composite transverse consultative US image at the level of the right femoral vein (*arrows*), before (left) and after (right) compression depicts full compressibility of the vein. **b** Longitudinal consultative US image at the level of the bifurcation of the right common femoral vein depicts normal flow on color Doppler. **c** Composite transverse point-of-care US image at the same level as (**a**) also depicts full compressibility of the vein. **d** Longitudinal point-of-care US image at the same level as (**b**) depicts normal flow on color Doppler

Fig. 4.

A 15-year-old girl with shock. Deep venous thrombosis on both consultative (**a** and **b**) and point-of-care (**c–e**) US. Transverse (**a**) and longitudinal (**b**) consultative US images at the level of the right internal jugular vein depict the presence of intravenous echoic material (*arrows*). **c–e** Transverse point-of-care US images at the same level depict the presence of intravenous echoic material (*arrow* on **c**), inability to fully compress the vein (**d**) and abnormal color Doppler flow (**e**)

Fig. 5.

A 5-month-old boy with acute respiratory failure. Deep venous thrombosis on consultative US (**a** and **b**) and normal scan on point-of-care US (**c**). **a–b** Transverse consultative US images at the level of the right internal jugular vein depict the presence of intravenous echoic material (*arrow* on **a**) and abnormal color Doppler flow (**b**). **c** No intravenous abnormality was convincingly identified at the same level on point-of-care US (*arrow* indicates location of vein). It seemed that there is a subtle veil-like shadow artifact along the left-most aspect of the image (*arrowheads*), which might have contributed to missing the finding. The remainder of the point-of-care US images (not shown) on this child did not demonstrate abnormal vein compressibility or abnormal color Doppler flow

a. Discordant Readings **b. Unevaluable Images** **Fig. 6.**

Association between fixed effects parameters and discordant readings (**a**) and unevaluable images (**b**). CVC central venous catheter

Table 1 Characteristics of children and images included in the study^a

Characteristic	All children (n=84)	Unevaluable images (n=23)	Evaluable images (n=129)	P-value ²
Pediatric intensive care unit				<0.001
Yale-New Haven Children's Hospital	44 (52.4)	20 (87.0)	60 (46.5)	
Maria Faren Children's Hospital	40 (47.6)	3 (13.0)	69 (53.5)	
Level of training of research personnel				0.03
Board-certified critical care physician	96 (63.2) ³	10 (43.5)	86 (66.7)	
Others	56 (38.2) ³	13 (56.5)	43 (33.3)	
Age in years	3 (0.3–11.7)	0.5 (0.2–8.3)	4 (0.3–11.6)	0.11
Weight in kg	13.1 (6.4–38.1)	8.6 (6.7–26.3)	15.6 (6.4–50.0)	0.07
z-score of weight for age	-0.2 (-1.6–1.0)	-0.2 (-2.3–1.1)	-0.1 (-1.4–1.1)	0.56
Male	49 (58.3)	8 (34.8)	80 (62.0)	0.02
Race				0.92
Non-Hispanic white	40 (47.6)	10 (43.5)	60 (46.5)	
Non-Hispanic black	12 (14.3)	3 (13.0)	18 (14.0)	
Hispanic	27 (32.1)	9 (39.1)	42 (32.6)	
Others	5 (6.0)	1 (4.4)	9 (7.0)	
Size of CVC in French	5 (4–5)	5 (4–5)	5 (4–5)	0.47
Laterality of CVC				0.22
Left	30 (35.7)	6 (26.1)	51 (39.5)	
Right	54 (64.3)	17 (73.9)	78 (60.5)	
Location of CVC				0.050
Femoral vein	38 (45.2)	6 (26.1)	64 (49.6)	
Subclavian vein	15 (17.9)	8 (34.8)	21 (16.3)	
Internal jugular vein	31 (36.9)	9 (39.1)	44 (34.1)	

Characteristic	All children (n=84)	Unevaluable images (n=23)	Evaluable images (n=129)	P-value ²
Timing of US				0.47
Entry	82 (53.9) ³	14 (60.9)	68 (52.7)	
Exit	70 (46.1) ³	9 (39.1)	61 (47.3)	
CVC in place during US	97 (63.8) ³	16 (69.6)	81 (62.8)	0.52

¹Values are expressed as count (%) or median (interquartile range).

²P-values refer to comparisons between the characteristics of unevaluable and evaluable images.

³The denominator for these characteristics is 152, which is the number of pairs of ultrasounds analyzed. CVC central venous catheter

Table 2 Comparison of consultative and point-of-care US images¹

		Consultative US	
		Positive for DVT (n=38)	Negative for DVT (n=114)
Point-of-care US	Positive for DVT	9 (23.7)	8 (7.0)
	Negative for DVT	23 (60.5)	89 (78.1)
	Unevaluable	6 (15.8)	17 (6.1)

¹Values are expressed as count (%). *DVT* deep venous thrombosis.

Table 3

Diagnostic accuracy of point-of-care US in diagnosing central venous catheter-related deep venous thrombosis confirmed by consultative US^I

	Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)	Negative predictive value (95% CI)
Overall	28.1% (13.7%–46.7%)	91.8% (84.4%–96.4%)	52.9% (27.8%–77.0%)	79.5% (70.8%–86.5%)
Femoral vein	29.4% (10.3%–56.0%)	93.6% (82.5%–98.7%)	62.5% (24.5%–91.5%)	78.6% (65.6%–88.4%)
Subclavian vein	0% (0%–70.8%)	83.3% (58.6%–96.4%)	0% (0%–70.8%)	83.3% (58.6%–96.4%)
Internal jugular vein	33.3% (9.92%–65.1%)	93.8% (79.2%–99.2%)	66.7% (22.3%–95.7%)	78.9% (62.7%–90.4%)

^I Values were calculated from evaluable images only. *CI* confidence interval.