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Measurement of vein diameter for peripherally inserted central catheter (PICC) insertion: an observational study

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Abstract

Choosing an appropriately sized vein reduces the risk of venous thromboembolism associated with Peripherally Inserted Central Catheters (PICCs). This observational study described the diameters of the brachial, basilic and cephalic veins and determined the effect of patient factors on vein size. Ultrasound was used to measure the veins of 176 participants. Vein diameter was similar in both arms regardless of hand dominance and side. Patient factors including greater age, height and weight as well as male gender were associated with increased vein diameter. The basilic vein tended to have the largest diameter statistically; however, this was the case in only 55% of patients.

Introduction

Peripherally Inserted Central Catheters (PICCs) are non-permanent vascular access devices that are used in a wide range of patient groups for longer term treatment and the infusion of irritating medications such as chemotherapy.[1] These devices are associated with complications such as venous thromboembolism (VTE) which interrupts treatment and is associated with morbidity and mortality. [2, 3] Both patient and insertion factors interact to increase the risk of VTE. [4] An important insertion factor is the degree of stasis from the disruption of blood flow due to the presence of the catheter. It is thought that the catheter to vein ratio (proportion of the vein taken up by the catheter) is a controllable factor in the reduction of thrombosis rates in patients who have a PICC inserted. [5] Current guidelines for PICC insertion recommend that the smallest diameter catheter that meets the treatment needs of the patient be inserted into the largest diameter vein. [6] Hence it is necessary to identify the largest vein to insert the catheter.

Ultrasound is the preferred method for vasculature assessment. Often, however, both arms are not assessed using ultrasound prior to insertion. Arm and vein choice may be based on inserter or patient preference as well as institutional guidelines. [7,8] Many clinicians prefer right sided insertion due to an easier anatomical pathway to the superior vena cava. [3, 9] Other clinicians mostly insert into a vein on the left side as the patient's non-dominant arm is preferred presumably due to perceived ease of self-care. [8] It is unknown whether these practices utilise the largest vein, as there is little published literature to inform which vein might be the most suitable to use for PICC insertion and patient factors that influence vein diameter.

Background

Literature investigating the effect of hand dominance on vein dimension centres on the measurement of the area of veins in the central circulation. Hand dominance or the preference for the use of one arm for most activities exists across the global population with an estimated 85% identifying the right hand as dominant. [10] Conflicting results have been found in research that has investigated the influence of hand dominance on axillary and jugular vein areas. A prospective, observational study by Tan and colleagues that involved 50 surgical patients examined the effect of hand dominance on the infraclavicular axillary vein using ultrasound. [11] The authors found that hand dominance did not influence the dimensions of this vein. Conversely, in the same year a retrospective study that used computed tomography to measure the cross sectional area of the internal jugular vein (n=80) found vein size was correlated with hand dominance. [12] Although no research could be identified that investigated the effect of hand dominance on upper arm vein diameter it could be surmised that hand dominance would have greater effect on the more peripheral basilic, brachial and cephalic veins of the upper arm and the dominant arm would have larger diameter veins due to increased use. [13]

Arm side (right versus left) does not appear to be correlated with vein diameter in the upper arm. When the diameters of the right and left basilic veins were compared in a prospective cadaver study in Brazil (n =13), commensurate diameters were found on both sides.[14] Similarly, in a larger retrospective study (n=3206) with live subjects examining the diameters of the cephalic vein in a vascular patient population, comparable mean vein diameters were found on each side. [15]

No published research could be identified that has formally analysed the diameter of veins used for PICC insertion by vein type. Despite this, the basilic vein is often put forward by clinicians as the largest vein and the cephalic the smallest. Certainly, previous research indicates that the basilic vein is preferred for insertion. [9, 16, 17] Literature investigating vein diameter for arteriovenous fistula (AVF) development does support the idea that the basilic and brachial veins have greater diameters than the cephalic vein. [15, 18] Vein diameters were measured at the mid-humeral level (which is close to the PICC insertion point), and the authors found that the brachial and basilic veins were of similar diameter (mean diameter

4.9mm and 5mm respectively) and the cephalic vein more than half that diameter (mean diameter 2.4mm). [15, 18]

To inform clinical practice there is a need to provide evidence regarding upper arm vein diameters and patient factors that influence vein size. This will enable clinicians to practice from an evidence-base to identify the largest vein for PICC insertion to reduce the risk of thrombus.

Aim

The aim of this study was to determine the effect of hand dominance, arm side (right versus left) and vein type on vein diameter.

Methods

Design

This observational, prospective study was set in a large metropolitan teaching hospital where a nurse-led PICC service operates within the Radiology Department. Patients who were booked for a PICC or midline were included as vein measurement rather than device type was the focus of the study. PICCs and midlines are both inserted peripherally in the basilic, brachial or cephalic vein approximately 10 centimetres above the ante-cubital fossa but are differing lengths. The tip of the midline sits in the axilla region whilst the PICC is longer, terminating in the central circulation. [1] Midlines are predominantly inserted for intravenous antibiotics for a period of up to four weeks.[19]

Participants

All adult (18 years or older) patients who had a PICC or midline inserted between May to December 2013 by the lead PICC inserter in the Radiology Department were approached to participate. Participants were excluded if they were unable to provide informed consent due to neurological or language barriers, had factors that prevented the measurement of both arms and those who reported being ambidextrous.

Power analysis

A power analysis was conducted using Pass 11. Based on multiple regression with an expected r^2 of 0.10 for variability due to hand dominance and r^2 of 0.50 for the proportion of variance in arm dominance due to the independent variables age, gender, arm side, diagnosis type, weight and height with 90% power and a 0.05 significance level it was found that 45 participants were required. However, for multiple linear regression, it is recommended that at least 10 subjects are required for each parameter in the model to avoid over-fitting. We therefore opted for a much larger sample, namely 176 patients.

Procedure

All measurements were performed by the lead PICC nurse who had previously demonstrated the ability to reliably and consistently obtain vein diameter measurements. [20] The validity of ultrasound to measure vein diameter has been established previously. [21, 22] Participants were in supine position with both arms supported at a 90 degree angle to the body by a platform. The elbow crease of both arms were marked when the arm was bent and another mark 10cm proximal from the first was determined using a measuring tape once their arm was straightened. The arms were in a natural state without tourniquet. A SonoSite™ S-Series ultrasound (SonoSite, Bothell, WA) with a 13-6 MHz linear probe was used to image the vein. Inbuilt calipers were used to measure the anteroposterior diameter of the vein from the image. This was performed on the basilic, brachial and cephalic veins in transverse section on both arms. This method has been used to measure vein diameter in previous research and is often used clinically to assess vein diameter for PICC insertion. [13, 23]

The transducer was moved along the second mark until the relevant vein could be visualised and was angled from left to right to obtain the clearest image of the vein. Light transducer pressure was used to reduce vein compression and gain/depth was optimized for each image. Where two brachial veins were present, the larger diameter vein was measured. Some veins could not be located or were unable to be measured accurately due to their small size. The superficial nature of the cephalic veins of some participants meant that even minimal transducer pressure caused too much distortion to measure accurately. Further, some were unable to be compressed (due to asymptomatic thrombi). In all of these cases the individual vein measurements were excluded from analysis.

The PICC-nurse was blinded to the patient's hand dominance. After vein measurement was completed on both arms, participants were asked to indicate their dominant arm (which was defined as the hand they preferred to write with). Height and weight was obtained from the medical record or from the participants.

Data analysis

Simple frequencies were used to describe demographics and diagnoses of the participants. Univariate and multivariate analysis was conducted using linear mixed effects regression models. Univariate analysis determined the effect of age, gender, weight, height and diagnosis on mean vein diameter. Multivariate analysis determined the effect of vein type, hand dominance and arm side on mean vein diameter which was adjusted for gender, age, height and weight. Analysis was performed using STATA version 12 (STATA Corp, College Station, TX). A p-value was set at <0.05 for statistical significance.

Ethics

Approval was granted by the Human Research Ethics Committees of the University and the Hospital where the study was conducted prior to the study's commencement (Protocol no. 31301 and 130217 respectively). After the research project was outlined to potential participants they were given a written information sheet by the researcher and allowed time to read it. Written consent was obtained.

Results

Participants

Participants were recruited from the waiting area of the Radiology Department. Of the 296 assessed for eligibility, 59 declined to take part and 61 were excluded. For those excluded, 47 were unable to consent due to confusion, dementia, low Glasgow Coma Scale score or inability to read, write or understand English; 5 were ambidextrous; and, 9 were unable to extend their arms to a 90 degree angle. The veins of 176 participants were measured. The mean age of participants was 58 years (SD 15.62), mean weight was 79Kg (SD 20.86) and mean height was 1.69 m (SD 0.10). Further participant information is presented in table 1.

Table 1: Participant demographic characteristics

Characteristic		Number	Percentage
Gender			
	Male	98	56%
	Female	78	44%
Hand dominance			
	Left	16	9%

Right	160	91%
Primary diagnosis		
Solid tumour	50	28%
Haematological malignancy	36	20%
Infection	80	46%
Other	10	6%

A small number of participant veins were unable to be located or measured at the measurement mark. These included five absent basilic veins (5/352; 1.42%) and eight that were unable to be measured (8/352; 2.27%). Of the basilic veins that were unable to be measured, seven were thrombosed and one was scarred. There was one absent brachial vein (1/352; 0.28%) and three that were unable to be measured (3/352; 0.85%). Of the brachial veins that were unable to be measured, two were thrombosed and one was too small to accurately measure. There was 14 absent cephalic veins (14/352; 3.98%) and 18 that were unable to be measured (18/352; 5.11%). Of the cephalic veins that were unable to be measured, 14 were thrombosed and four were too small to accurately measure. Vein diameter range was 0.70-7.30mm for the basilic vein, 0.60-7.10mm for the brachial vein and 0.15- 6.10mm for the cephalic vein.

Patient factors and mean vein diameter

Based on univariate analysis, mean vein diameter (of the six veins combined) was statistically significantly greater in male, taller, heavier and older patients, however, the differences were small for most of these variables (table 2). The largest difference in vein diameters was observed in male participants, who had a mean vein diameter more than half a millimeter larger than females. The diagnoses of participants were not associated with a difference in vein size.

Table 2: Univariate analysis of patient factors associated with vein size (mm)[a]

Variable		B	95% CI (B)	Sig.*
Age	Year of age	0.007	0.001 to 0.013	0.030
Gender	Male vs Female	0.581	0.407 to 0.754	<0.001
Weight	Kg	0.016	0.012 to 0.020	<0.001
Height	cm	0.021	0.012 to 0.030	<0.001
BMI	Kg/m^2	0.036	0.023 to 0.050	<0.001
Diagnosis type	Infection vs Solid tumour	-0.180	-0.407 to 0.047	0.120
	Infection vs Haematological cancer	0.055	-0.200 to 0.309	0.674
	Infection vs Other	0.037	-0.400 to 0.475	0.867

[a] all vein types combined*analysed by univariate linear mixed effects model; BMI=body mass index Kg=kilogram; cm=centimetre; m=meter; B = regression co-efficient

Hand dominance and arm side

There were no statistically significant differences in mean diameter (of the three veins combined) between the dominant and non-dominant arms (table 3). This did not change markedly after adjustment for age, height, gender and weight. There was even less of a difference in mean vein diameter when right versus left side was analysed which also did not change after adjustment for the same variables.

Table 3: Association between hand dominance/arm side and mean vein diameter (mm)

	Unadjusted		**Adjusted [a]**	
	B (95% CI)	Sig*	B (95% CI)	Sig*
Hand dominance	0.076 (-0.061 to 0.213)	0.279	0.074 (-0.064 to 0.212)	0.293
Arm side	0.027 (-0.109 to 0.164)	0.694	0.038 (-0.101 to 0.176)	0.594

[a] adjusted for age, gender, weight and height
* Analysed by multivariate linear mixed effects model; B= regression coefficient; 95% CI = 95% confidence interval

Vein type

The variables arm side, hand dominance, diagnosis type and height were not associated with a difference in the diameter of veins when analysed by vein type. The effect of other variables differed for each vein type. Male gender (B 0.586; 95% CI 0.275-0.870; p<0.001) and increased weight (B 0.004; 95% CI 0.001-0.870; p<0.001) were associated with increased basilic vein diameter, whereas age was not. For the brachial vein, male gender (B 0.688; 95% CI 0.450-0.926; p<0.001) and increased age (B 0.183; 95% CI 0.011-0.026; p<0.001) was predictive of larger brachial vein diameter, but increased weight was not. Only increased weight was associated with a difference in cephalic vein diameter, although the actual difference was small (B 0.002; 95% CI 0.002-0.009; p=0.004).

When the mean vein diameters of the different vein types were compared, the diameter of the participant's basilic veins was statistically significantly greater than the diameters of their brachial and cephalic veins. On average the diameter of the basilic was 0.46mm greater than the brachial vein and 0.89mm greater than the cephalic vein (table 4). This difference remained after adjustment for age, gender, weight and height. Although statistically, there were differences between the mean vein diameters according to vein type, the basilic vein did not always have the largest diameter when the location of the largest vein was determined. Notably, where all six veins could be measured, the basilic vein was the largest in only 55% of participants, the brachial vein largest in 28% and the cephalic vein largest in 17%.

Table 4: Association between vein type and mean vein diameter (mm)

	Unadjusted		Adjusted [a]	
	B (95% CI)	Sig*	B (95% CI)	Sig*
Basilic vs. brachial	-0.455 (-0.609 to -0.300)	<0.0001	-0.448 (-0.604 to -0.292)	<0.0001
Basilic vs. cephalic	-0.886 (-1.044 to -0.727)	<0.0001	-0.890 (-1.05 to -0.730)	<0.0001

[a] adjusted for age, gender, weight and height
*analysed by multivariate linear mixed effects model; B= regression coefficient; 95% CI = 95% confidence interval

Discussion

This study found that hand dominance and arm side were not associated with upper arm mean vein diameter. This research is unique in that it specifically examined the upper arm veins used for PICC insertion, but it does support previous research which found arm side and hand dominance was not correlated with vein diameter. [11, 14, 15]

The findings of the present study indicate that either arm could contain the largest vein. Hence both arms should be considered for PICC insertion. Yet some authors suggest that left-sided insertion should be avoided due to increased risk of VTE. A higher rate of thrombus was found with left-side insertion in a recent case-control study (n 400). [24] The authors proposed that left- side insertion increases risk of thrombus due to longer catheter length (and hence greater thrombogenicity) as well as reduced blood flow of the brachiocephalic vein on that side. But most research has not demonstrated an association between left-side insertion and risk of thrombus. [2, 3, 25, 26] Vasculature assessment using ultrasound of both arms should guide insertion site decisions.

Vein type

A unique finding of this study was the location of the largest vein. On average the basilic vein had a greater mean diameter than the brachial and cephalic veins. However, when the largest diameter by vein type was identified, the basilic had the largest diameter in only half of the sample. Notably, the cephalic vein was the largest vein in 17% of participants. Previous research suggests that larger catheters are associated with higher rates of DVT. [9, 16, 27] It could be assumed this is due to increased stasis hence the need to insert into the largest vein to reduce this risk. [28] Clinicians should be cognisant that if they limit vein choice (due to ease of insertion or institutional norms) they may not be utilising the patient's largest vein and may be increasing their risk of VTE. The results of the present study indicate that any of the veins may have the largest diameter. Yet the basilic vein is often preferred for insertion and the cephalic vein is put forth by some as the 'vein of last resort'.[17] A much cited study by Allen and colleagues does support the avoidance of the cephalic vein for insertion. Participants with a PICC inserted in a cephalic vein were 10 times more likely to develop a thrombus.[7] The authors proposed that higher rates of thrombus associated with cephalic vein insertion were due to smaller vein size, however, they did not measure vein diameter. More recent research has not replicated these findings. [24, 29]

Vein damage

The veins of some participants in the study were unable to be measured due to asymptomatic thrombus (non-compressible veins). This was more common in the cephalic veins where 4% were thrombosed. This is a small but clinically important rate; the damage to these veins meant that they were precluded from PICC insertion. Although not formally recorded in this study, many of the participants who had thrombosed veins stated they had numerous peripheral intravenous catheters (PIVC) inserted distally to the measurement point. They had not previously had a PICC or other central access device inserted. For one participant, three out of the six veins measured (both cephalic veins and one basilic vein) were non-compressible. The participant described multiple hospital admissions which included numerous surgeries and PIVC insertions. Although the definitive cause of asymptomatic thrombus in this study is unknown, PIVC insertion can lead to thrombotic complications that extend to vasculature in the upper arm. Previous research found 45% of participants (who had not previously had a PICC) had asymptomatic superficial thrombosis in veins in the upper arm after PIVC insertion in the forearms. [8] However, this study was based on a small sample size (n=29) and a baseline assessment was not performed which would identify pre-existing thrombus.

The insertion of PIVCs is one of the most common invasive procedures performed in a hospital yet vasculature assessment is limited to visual assessment and palpation. [30] A recent Infusion Nurses Society position paper recommends the use of vein visualization technology such as ultrasound to guide difficult PIVC insertion. [31] Potentially ultrasound could be used for all patients to determine vessel health prior to vascular access device insertion. This would facilitate an individualised and proactive plan of vascular access to protect vessel health.[32] This is especially important for those who have chronic health conditions that require repeated vascular access device insertions for intravenous therapy.

Limitations

The study was limited by the inclusion of participants from a single center site; however, it is the major metropolitan trauma and teaching hospital in the region with a wide range of specialties and hence the patient population is likely to be representative of similar hospitals. Any study where measurement is influenced by the operator clearly has the potential for bias. However, every effort was made to control for this with the use of a consistent approach to measurement.

Conclusion

This study found that hand dominance and arm side were not associated with differences in vein diameter. Patient factors including age, height and weight as well as male gender are associated with increased vein diameter. The basilic vein tends to have the largest diameter statistically; however, this is not the case in all participants. This research has demonstrated the importance of a full assessment of the basilic, brachial and cephalic veins of both arms to ensure that the largest and healthiest vein is identified for PICC insertion. Vein measurement using ultrasound should guide practice as each consumer's vasculature is unique.

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