# Peripheral vascular access from the arms for electrophysiology procedures using ultrasound guidance

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**Abstract**

Introduction Vascular access has traditionally been gained from the femoral vessels, however, a 'radial-first' approach has become increasingly popular and resulted in lower complication rates and reduced healthcare costs. A "superior" approach has been reported for electrophysiology (EP) studies but is associated with an increased risk. To provide comprehensive anatomical evidence that the vessels of the arms are suitable for use during EP procedures, as assessed by vascular ultrasound. Methods A portable ultrasound device was used to measure the diameter of the brachial artery, brachial, basilic & cephalic veins on the left and right upper limbs of 63 healthy volunteers. A subgroup of 15 volunteers had additional measurements taken with a tourniquet. Results The basilic vein had the largest diameter with a median of 4.6 mm and 4.5 mm (right and left diameter, respectively), followed by the cephalic (median of 3.1 and 3.0 mm) and the brachial vein (median of 2.8 mm). 100% of volunteers had at least one vein that was equal to a 3 mm diameter (which would allow for an 8F sheath), with 98% having 2 suitable veins and >80% having 3 suitable venous vessels. More than 90 % had a suitable diameter for both the right and left brachial artery. There was no correlation between BMI, height, weight, but men had significantly larger basilic veins and brachial arteries ($p<0.05$). Conclusion We demonstrate the anatomic evidence that the vessels in the arm(s) are capable of housing the size of sheath commonly used in the EP lab.

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Introduction

Vascular access has traditionally been gained from the femoral vessels, however, a 'radial-first' approach has become increasingly popular and resulted in lower complication rates and reduced healthcare costs. A "superior" approach has been reported for electrophysiology (EP) studies but is associated with an increased risk. To provide comprehensive anatomical evidence that the vessels of the arms are suitable for use during EP procedures, as assessed by vascular ultrasound.

Methods

A portable ultrasound device was used to measure the diameter of the brachial artery, brachial, basilic & cephalic veins on the left and right upper limbs of 63 healthy volunteers. A subgroup of 15 volunteers had additional measurements taken with a tourniquet.

Results

The basilic vein had the largest diameter with a median of 4.6 mm and 4.5 mm (right and left diameter, respectively), followed by the cephalic (median of 3.1 and 3.0 mm) and the brachial vein (median of 2.8 mm). 100% of volunteers had at least one vein that was equal to a 3 mm diameter (which would allow for an 8F sheath), with 98% having 2 suitable veins and >80% having 3 suitable venous vessels. More than 90 % had a suitable diameter for both the right and left brachial artery. There was no correlation between BMI, height, weight, but men had significantly larger basilic veins and brachial arteries ($p<0.05$).

Conclusion

We demonstrate the anatomic evidence that the vessels in the arm(s) are capable of housing the size of sheath commonly used in the EP lab.

## Introduction

Vascular access for invasive cardiac investigations has traditionally been gained from the femoral vessels.[1] Transfemoral access (TFA) is a safe and simple procedure which allows for repeated puncture,[2] however a 'radial-first' approach has become increasingly popular for coronary interventions.[1] Transradial access (TRA) has lower complication rates, shorter admission times, and reduced healthcare costs, when compared to TFA.[3-5] Additionally, right heart catheterisation using the antecubital vein has recently been shown to be safe and effective.[6]

The use of a "superior", non-femoral approach for electrophysiology (EP) studies and radiofrequency catheter ablation (RFCA) via the jugular and subclavian veins has been reported, but is associated with an increased risk of complications such as pneumo- and haemothorax.[7-11] We recently reported two cases of successful catheter ablation exclusively from the arm vessels.[12] EP procedures often require the use of both venous and arterial catheters, and the potential advantages of non-femoral peripheral access is yet to be investigated.

We present comprehensive anatomical evidence that the vessels in the arms are suitable for use during EP procedures, as assessed by vascular ultrasound.

## Methods

Five of the authors, trained in assessing peripheral vasculature, examined healthy adult volunteers with no pre-determined inclusion criteria. Basic demographic data such as age, gender, height & weight as well as BMI was documented (Table 1).

### Ultrasound-based vascular assessment

A portable ultrasound device (L12-4 high frequency transducer, Philips Lumify) was used to measure the diameter of brachial artery, brachial vein, basilic vein & cephalic vein on the left and right upper limbs (Figures 1 + 2). The probe was calibrated in the transverse section with the depth and gain adjusted to suit the operator and the subject density. Light compression was applied to allow differentiation of the artery and vein(s). If there was any ambiguity, colour doppler assessment was performed. After freezing the image, the calliper tool was used to measure the vein or artery (in millimetres) from the inner anterior to the inner posterior border of the vessel, with minimal pressure on the skin to measure maximal diameter. In addition, a measuring tape was used to measure circumference at the elbow and at the mid-bicep level on both arms (Figure 2C).

### Effect of tourniquet application

To demonstrate the effect of a tourniquet, a subgroup of 15 volunteers had additional measurements taken of the same veins and artery on both arms with a tourniquet at the upper bicep level (Figure 2B).

### Statistical analysis

Continuous variables are presented as mean ± standard deviation, or median and interquartile range if not normally distributed. Categorical variables are summarized by frequencies and percentages. Baseline characteristics and procedural variables are compared using the student t-tests, Wilcoxon signed-rank test, or Fisher's exact test where appropriate. A two-tailed p value $<0.05$ was considered statistically significant. All calculations were performed with the software package R version 3.5.0 (http://cran.r-project.org/).

## Results

A total of 63 volunteers with a mean age of 38.2 ± 14.1 years were recruited into the study. Of those 36 (57%) were females. Table 1 summarizes the basic demographics of the volunteers with the majority of them being right hand dominant (88%).

### Results of the ultrasound-based assessment (Table 2)

In all volunteers the quality of the ultrasound assessment was sufficient to obtain adequate imaging. Typically, the basilic vein was found to have the largest diameter with a median of 4.6 mm and 4.5 mm (right and left diameter, respectively), followed by the cephalic (median of 3.1 and 3.0 mm) and the brachial vein (median of 2.8 mm for both arms). There was no significant difference between right and left median vessel diameters. (Figure 3A).

Overall, median vessel diameter was significantly different between male and female volunteers (Table 2), with the basilic veins remaining the largest for both genders. There was significant difference between genders, for basilic vein (p-value 0.0091 for right & 0.016 for left using independent two sample t-test) and brachial artery diameters (p-value $1.1\text{x}10^{-5}$ for right & $8.3\text{x}10^{-5}$ for left). There was no correlation between BMI, height, weight, and elbow or bicep circumference.

### Effect of tourniquet application (Table 3, Figure 3B)

In a subgroup of 15 volunteers, additional measurements of venous and arterial diameters were taken with a tourniquet applied. There was a decrease in the median diameters of the arterial vessels of -11.9% (median of 0.1 mm) and -5.4% (median of 0.2 mm) for the right and left brachial arteries, respectively. The median change for the right brachial vein was +13.3% (0.4 mm), with no change for the left brachial vein (both 3.2mm). For the right basilic vein, the median change was +8.9% (0.4 mm) and +8% (0.4 mm) for the left basilic vein. The biggest change was demonstrated in the cephalic veins with +37.5% (1.2 mm) for the right and +23.3% (0.7 mm) for the left cephalic vein.

To demonstrate the suitability of inserting an 8F sheath (which has an outer diameter of 2.6 mm), figure 3A plots the vessel diameter of the basilic, brachial, and cephalic veins, as well as for the brachial artery, against the percentage of volunteers with the diameter in question. In 100% of volunteers at least one vein was equal to a 3 mm diameter, with 98% having 2 suitable veins and >80% having 3 suitable venous vessels in both arms (Figure 4). With regards to the arterial diameters, more than 90 % had a suitable diameter of more than 3 mm for both the right and left brachial artery.

Discussion:

To our knowledge, this is the first paper to investigate he feasibility of adopting peripheral access in the electrophysiology lab. The main findings are: 1) 100% of volunteers examined had one vein which was at least 3mm in size and would be suitable for 8F catheter insertion; 2) more than 90% of volunteers examined had at least 2 suitable veins; and 3) there was no correlation between BMI and vein diameter 4) Men had significantly larger basilic vein and brachial artery diameters ($p<0.05$) than women.

Learning from other specialties

It is now widely accepted that interventional cardiology procedures are safer and more effective when vascular access is gained from the arm.[4, 13] During the COVID-19 pandemic, many physicians at our tertiary centre were trained in the insertion of peripherally inserted central catheters, also known as PICC lines.[14] These lines are even placed in paediatric and neonatal patients and typically remain for several weeks to months in-situ.[15]

The advantage of peripheral vascular access from the arms for non-EP procedures has already been established in our centre for a number of years and include hemodynamic investigations in almost all patients with congenital heart disease or with suspected pulmonary hypertension. In most of these studies, a 7F (outer diameter 2.3 mm) sheath is placed using the same ultrasound-guided technique.

In the last years, two groups reported their experience of using "arm-only" access for neurointerventional procedures.[16] They concluded that the vessels of the forearms were too small (<2mm) and positioned their venous access sheaths ultrasound-guided either in the cephalic or basilic veins.

Potential advantages of peripheral access sites

A major advantage of this access route is that no bed rest is required. After the procedure, haemostasis can be easily achieved with compression devices (for arterial access) or simple manual compression for 5-10 min after venous access.[16-18] Patients can therefore be treated as day-case procedures with observation for several hours before discharge. Especially in times where in-patient bed capacities may be limited, this has obvious advantages. The alternative access routes via a jugular or subclavian puncture is always in close proximity to the lung fields, with high risk of local injury such as pneumo- or haemothorax.[19] Such superior access is recommended to be performed using ultrasound-guidance already from virtually all associations.[20-22] As the potential puncture site(s) demonstrated here are far away from the lung fields, additional post-procedural imaging such as chest x-rays to exclude post-procedural pneumothorax are not necessary.

A novel access route for EP procedures

Learning from the experience of our colleagues, it was hypothesised that this relatively simple procedure could be adapted for use in invasive studies and catheter ablation. We demonstrate the anatomic evidence that the vessels in the arm are capable of housing the size of sheath and catheters commonly used in the cath lab. In a recent report, we summarized our experience in using this technique to successfully perform catheter ablation procedures in the right and left atrium using the remote-controlled magnetic navigation system.[12]

Need for individualised approach

The anatomical course of the vessels of the arm is variable, although the classical configuration seems to be 2 superficially located veins with the cephalic vein on the lateral aspect and basilic vein on the medial aspect of the arm.[23] One or more brachial veins accompany the brachial artery which divides into the radial and ulnar artery at about the level of the elbow. However, anatomic studies on cadavers have described a number of variants of this distribution patterns.[24-26]

The role of ultrasound has become increasingly integrated into interventional cardiac procedures.[27] It enables visualisation of the vasculature, assessment of the depth and diameter of a vessel, and assessment of an optimal route for access. Additionally, it eliminates the guesswork involved in traditional puncture techniques, minimises the risk of entering the incorrect vessel, or puncturing the posterior wall, and subsequent development of haematomas. All of our participants had at least one basilic, brachial, or cephalic vein which was 3mm or greater. The largest vein in our cohort was the basilic vein, with a median diameter of 4.6mm on the right, and 4.5mm on the left. The ranges of diameters recorded varied considerably, and an individualised approach using ultrasound-guidance should be considered when considering peripheral vascular access in a given patient.

Effect of tourniquet application

In a small sub-cohort of participants, the effects of tourniquet application were studied. There was an increase in vein diameter between 4.9% and 17.8%, however a slight decrease in brachial artery diameter was noted. In patients who require both vein and artery catheterisation, it may be beneficial to apply a tourniquet when puncturing the veins and releasing it on insertion of arterial sheath.

Limitations

In this study, besides the small sample size, we have studied healthy volunteers which may differ from a real patient cohort presenting with arrhythmia-related symptoms. Our cohort was young and presented with an only slightly increased BMI which may therefore be non-representative for the average EP patient. A prospective study of patients admitted for EP studies or catheter ablation is in preparation.

Of note is that we did not apply any vasodilatory drug (topical or intravascular)[28, 29] or utilise palmar warming[30] to dilate the vessels, which is a commonly used technique in radial access coronary interventions. It is unclear if any of these measures would have any effect on venous vessel diameters as well.

Conclusion

Vascular access for invasive EP procedures via the vessels of the upper arm using ultrasound guidance seems very feasible, as shown by our entire cohort of volunteers having at least one vessel diameter of 3mm or larger. Clinical experience from other invasive interventional procedures such as right heart catheterisation, coronary interventions, and neuro-interventions should pave the way for a novel peripheral access route for electrophysiologic procedures.

Figures

1. Schematic of the vascular system of upper limbs. Courtesy of Prof. Yen Ho, Brompton Cardiac Morphology Unit, Royal Brompton Hospital, London (UK).
2. (A) Ultrasound image obtained differentiating upper limb artery (A) from vein (V). (B) Ultrasound probe position shown for obtaining image of the basilic vein with tourniquet placement at the upper bicep level. (C) Drawing of upper limb to show level measurements taken for the circumference at the mid bicep level and at the elbow.
3. (A) Box plots showing median vessel diameters for all respective veins and brachial artery for right and left arm for the entire patient cohort. (B) Box plot showing median vessel diameter without tourniquet placement (left box) & with tourniquet placement (right box) for left (L) and right (R) arms (n=15).
4. Line graph showing vessel diameter of the basilic, brachial, & cephalic veins and the brachial artery, against the percentage of volunteers with the diameter in question for both right and left arms for the

entire cohort (n=63).

Tables

1. Basic demographics of volunteers recruited into the study
2. Median diameters ($1^{st}$ - $3^{rd}$quartile) of right (R) & left (L) arm vessels of male & female volunteers. Significance obtained using Wilcoxon signed-rank test for vessel diameter difference between right vessel and left vessel.
3. Effect of tourniquet application (n=15) on median diameter of right (R) & left (L) arm vessels. Significance obtained using Wilcoxon signed-rank test for vessel diameter difference with tourniquet applied.

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