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Ultrasonographic Identification of the Proximal Humerus Landmarks for Intra-Osseous Vascular Access across Different Body Habitus

An observational study to determine if there is consistency in ultrasonographic landmark identification of the proximal humerus across various body habitus

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Study Summary

Title	***Ultrasonographic identification of the proximal humerus landmarks for Intraosseous Vascular access across different body habitus***
Short Title	Ultrasonographic landmark identification of the proximal humerus
Principal Investigator	Sergio Bustamante, MD
Primary Objectives	Evaluate whether discrete landmarks of the proximal humerus can be identified using ultrasound in patients with various body habitus and BMI.
Primary Endpoints	Ability to identify the following 6 anatomical landmarks for proximal humerus interosseous venous access with ultrasound: 1. Humeral shaft, 2, Surgical neck of the humerus, 3. Lesser tubercle, 4. Greater tubercle, 5. Intertubercular sulcus 6. Target site for needle insertion in the greater tubercle.
Secondary Objectives	- Evaluate the time used to identify all 6 anatomical landmarks using ultrasound. - Evaluate the depth of each landmark from skin under ultrasound. - Correlate the Arm thickness with the depth of the anatomical structures. - Correlate the BMI with the depth of the anatomical structures.
Secondary Objectives Measures	- Time used to identify all 6 anatomical landmarks in seconds. - Depth of each anatomical landmark from skin in centimeters.
Study Design	A single institution observational study
Inclusion Criteria	1- Males or females 18 years of age or older. 2- BMI $\geq$ 18.5
Exclusion Criteria	1. Limited mobility/ range of motion of arms 2. Prior surgical intervention on shoulder or humerus 3. History of arm dislocation with internal rotation 4. History of arm fracture 5. BMI in ranges: 25.1 – 29.9, 35.1 – 39.9
Expected Sample Size	30 Patients (60 exams)
Statistical Methodology	We will summarize the total number of correctly identified landmarks per patient overall and by BMI category. We will also estimate the incidence of correctly identifying all landmarks per patient with a 95% bootstrap confidence interval.

List of Abbreviations

Abbreviation	Definition
BMI	Body Mass Index
CFD	Color Flow Doppler
CV	Central Venous
IO	Intraosseous
PH	Proximal Humerus
PHIO	Proximal Humerus Intraosseous
PHIOVA	Proximal Humerus Intraosseous Vascular Access
PIV	Peripheral Intravenous

1 Introduction

This document is a protocol for a human research study. This study is to be conducted according to US and international standards of Good Clinical Practice (FDA Title 21 and International Conference on Harmonization guidelines), applicable government regulations and Cleveland Clinic research policies and procedures.

1.1 Background and Rationale

Establishing vascular access is of vital importance during resuscitation of cardiac arrest, trauma and during various intraoperative scenarios. During cardiac arrest minimizing time wasted without performing chest compression is vital to successful resuscitation, therefore, being able to establish vascular access quickly can save lives[1]. Intraoperatively, the ability to rapidly obtain vascular access is crucial to maintain hemodynamic stability. Similarly, having adequate vascular access is the cornerstone for resuscitation in trauma patients.

Three main forms of vascular access are used in the scenarios above: peripheral intravenous (PIV), Central venous (CV) and intraosseous (IO). Of the different types of vascular access PIV and CV access have drawbacks when used during resuscitation[2], because they can be difficult to obtain when patients are volume depleted as in cases of trauma. Attempting CV access has numerous risks with complications occurring in up to 33% of attempts. These include failed placement (22%), arterial puncture (5%), catheter malposition (4%), pneumothorax (1%) and asystolic cardiac arrest (<1%)[3]. Attempting to obtain CV access may also disrupt chest compressions in cases of cardiac arrest. Intraosseous access has been used in scenarios where PIV and CV access is difficult or impossible to obtain. Pharmacokinetic studies and standard practice support the bioequivalence of intraosseous and intravenous administration of common medications[4]. Intravascular depletion does not hinder attempts at IO access, and as the insertion sites are peripheral to the heart, insertion can be done avoiding interruptions in chest compressions. Obtaining proximal humerus interosseous (PHIO) access may also be faster than obtaining both PIV and CV access with a relatively low complication rate[2]. In one survey of Scandinavian users, complications of IO included difficulty in identifying correct anatomical site (3%), extravasation (3.7%), displacement after insertion (8.5%), and very rarely late complications including compartment syndrome (0.6%), osteomyelitis (0.4%) and skin infection (0.3%)[5].

The site that has been used most commonly for IO access has been the proximal anterior tibia because of ease of landmark identification and provider familiarity. The proximal humerus (PH) has recently gained more attention and is a viable alternative to the anterior tibia because of decreased pain with initial bolus, decreased medullary pressure resulting in more rapid fluid delivery and is in closer proximity to the heart[6].

Proximal humerus interosseous access relies on landmark identification of the greater tubercle via palpation of the surgical neck of the humerus. This method can be especially difficult in patients with prominent deltoid musculature or adipose tissue overlying these landmarks. Failure to identify landmarks is an absolute contraindication to IO access[1]. Success rates for PHIO needle insertion have been cited as low as 76% in one study compared to 92% for proximal tibial insertion[7]. Moreover, a failed IO needle insertion precludes the immediate use of the same site for another trial.

Ultrasound identification of PH structures on cadavers has recently been described in the literature and has the promise of increasing the success rate of what is now considered a blind procedure[8]

1.2 Clinical Data to Date

Ultrasound identification of proximal humeral structures is a novel concept with no current case reports or clinical trials demonstrating its use in clinical practice.

A correspondence letter by Bustamante et al.[8] demonstrated the use of ultrasound to identify PH structures on a cadaver model. Structures identified were the greater and lesser tubercles, intertubercular groove and surgical neck. Identification of these structures are necessary for PHIO needle placement. A 13-6 MHz ultrasound linear probe (SonoSite Inc; Bothell, Washington, USA) was used to identify these structures on 5 cadavers with body max indexes (BMI) ranging from 20 – 35. All structures were relatively superficial, within 3cm from the skin. Once landmarks and target site were identified, an IO needle was inserted and placement was confirmed with color flow doppler (CFD).

Failure to identify proximal humeral structures is considered an absolute contraindication to attempting PHIO placement. Prominent deltoid musculature and adipose tissue overlying proximal humeral landmarks can make identifying proximal humeral structures by palpation difficult if not impossible. As failed PHIO access of one arm precludes the use of the same arm for subsequent trials the first attempt must be optimized to allow for the greatest chance for success. If ultrasound is found to successfully identify all landmarks, even in patients with higher BMI's, failure to identify landmarks by palpation will no longer be considered an absolute contraindication.

2 Objectives

2.1 Primary Objectives:

Estimate the ability to successfully identify each of the six proximal humerus anatomical landmarks required for proximal humerus interosseous vascular access (PHIOVA), using ultrasound in patients with different body habitus: BMI 18.5-25 kg/m^2, BMI 30-35 kg/m^2, and BMI > 40 kg/m^2.

2.2 Secondary Objectives:

- Estimate the time used (in seconds) to identify all 6 anatomical landmarks using ultrasound in patients with different body habitus.
- Estimate the depth of each landmark (in centimeters) from the skin using ultrasound in patients with different body habitus.
- Estimate the correlation between upper arm thickness and the depth of the anatomical structures.
- Estimate the correlation between BMI and the depth of the anatomical structures.

3 Primary hypothesis

We will test the hypothesis that all 6 anatomical landmarks for proximal humerus interosseous venous access can be identified using ultrasound in all patients irrespective of their BMI, or mid upper arm circumference.

4 Study Design

4.1 General Design

- An observational study performed on adult patients undergoing general, cardiac, thoracic or vascular surgery.
- Demographic data collected include age, sex, weight (kg), Height (cm)
- BMI, and mid upper arm circumference will be measured or calculated for all subjects.

The study procedure will be performed on each patient by two out of three investigators trained on performing an ultrasonographic exam of the proximal humerus using a linear probe. All investigators have at least one year of experience in ultrasonography with the linear probe and have participated in at least three (3) PHIO access workshops. (Sergio Bustamante, MD, Negmeldeen Mamoun, MD, and Shravan Cheruku, MD). Two investigators will perform an ultrasonographic exam on each patient, with one investigator examining each side. Investigator A will perform the exam and identify all 6 landmarks with ultrasound, while investigator B will time the exam starting from when the ultrasound probe is handled till all landmarks are identified. Investigator B's role is also to verify that landmarks are identified and document how many of the landmarks were seen from zero to six out of six per arm. After the exam is complete, the roles of investigator A and B are then switched to perform an exam on the contralateral humerus, where investigator B identifies landmarks on the opposite side and investigator A times the exam.

After the conclusion of the exam on each arm the depth of each landmark under ultrasound will be noted, and the mid upper arm circumference will be measured.

4.2 Primary Study Endpoints

- Ultrasound evaluation of the proximal humerus will aim at identifying 6 anatomical landmarks for PIHOVA with ultrasound:
    1. The humeral shaft,
    2. The surgical neck of the humerus,
    3. The lesser tubercle,
    4. The greater tubercle,
    5. The intertubercular sulcus
    6. The target site in the greater tubercle for needle insertion.

  Each arm will receive a score that ranges from zero to six out of six depending on how many landmarks were identified successfully.

4.3 Secondary Study Endpoints

- Time used to identify all 6 anatomical landmarks using ultrasound in seconds.
- Depth of each landmark from the skin using ultrasound in centimeters.
- Correlation between upper arm thickness and the depth of the anatomical structures.
- Correlation between BMI and the depth of the anatomical structures

5 Subject Selection and Withdrawal

5.1 Inclusion Criteria

1- Males or females, 18 years of age or older.

2- BMI $\geq$ 18.5

5.2 Exclusion Criteria

1. Limited mobility/ range of motion of any of the upper extremities.
2. Prior surgical intervention on shoulder or humerus in any of the upper extremities.
3. History of arm dislocation with internal rotation in any of the upper extremities.
4. History of arm fracture in any of the upper extremities.
5. BMI in ranges: 25.1 – 29.9, 35.1 – 39.9

5.3 Subject Recruitment and Screening

Participants will be selected after chart review of current patients undergoing general, cardiac, thoracic, or vascular surgery. Patients will be approached in the preoperative clinic or during their hospitalization (preoperatively or postoperatively). Informed consent will be obtained on the same day of performing the ultrasound exam.

Participants will be separated into 3 cohorts based on BMI. The number of participants in each cohort is as follows: 10 patients with BMI 18.5 – 25 kg/m^2; 10 patients with BMI 30-35 kg/m^2, 10 patients with BMI $\geq$ 40 kg/m^2.

6 Statistical methods

We will summarize the study population on baseline characteristics using appropriate summary statistics (e.g., mean ± standard deviation, median [Q1, Q3], or N (%)).

6.1 Primary Analysis

We will summarize the success of landmark identification overall and by BMI category. Landmark identification is considered successful if all 6 landmarks are identified correctly. We will estimate the incidence of correct identification of all landmarks with a 95% bootstrap confidence interval. We will use bootstrap confidence intervals instead of binomial confidence intervals to account for intra-subject correlation because landmark identification will be performed twice per subject.

We will also report the median [Q1, Q3] of the mean number of landmarks identified correctly per patient overall and by BMI category. Results will be presented in tables and appropriate graphs. Descriptively, we will summarize the percent of correct identification by landmark location.

6.2 Secondary Analyses

We will estimate the median [Q1, Q3] of the mean time in seconds to identify all landmarks using ultrasound overall per patient overall and by BMI category.

Depth of each landmark will be summarized overall and by BMI category using appropriate summary statistics (e.g., mean ± standard deviation and median [Q1, Q3]).

We will estimate the correlations between the following measures using Pearson correlation with 95% confidence intervals:

- Arm thickness with depth of anatomical structures
- BMI with depth of anatomical structures

Arm thickness, depth of anatomical structures, and BMI are only measured once per patient so standard methods are applicable (i.e., no repeated measures).

6.2 Sample Size Considerations

We will enroll 30 patients, with 10 patients in each BMI category: BMI 18.5-25 kg/m^2, BMI 30-35 kg/m^2, and BMI > 40 kg/m^2. Given that investigators will be highly trained, we conservatively assume all landmarks will be identified 80% of the time. We expect very weak intra-subject correlation. Ignoring intra-subject correlation, we expect 95% confidence interval widths as small as 0.22 for overall incidence of correct identification and 0.38 within each BMI category. Confidence intervals will be somewhat larger depending on the strength of intra-subject correlation. Confidence interval widths will be narrower if investigators are more than 80% successful at identifying landmarks.

Study enrollment will start with 3 pilot patients with different BMI, but they will not be included in the statistical analysis. Thereby, a total of 33 patients will be enrolled in our study

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