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Ultrasound Guidance as a Rescue Technique for Peripheral Intravenous Cannulation

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Abstract

Peripheral intravenous (IV) cannulation can be difficult to perform using the traditional landmark or visual/palpation technique in patients with access difficulties such as deep, sclerotic, small, or fragile veins. Ultrasound guidance has shown efficacy in expediting the cannulation of central veins, but there is limited information on its utility in facilitating cannulation in peripheral veins, particularly for patients with difficult access. The purpose of this study was to compare the use of ultrasound guidance versus traditional technique for placing peripheral IV's in patients with difficult access.

Patients were eligible for the study if they were over 18 years, not on steroid or anticoagulant therapy, required an 18 or 20 gauge IV, and had undergone two unsuccessful IV attempts by standard of care methods (non-ultrasound). After informed consent, patients were randomized to either traditional or ultrasound IV insertion by one of three trained study anesthesia providers. Data collected included number of attempts to start an IV, time to cannulation, and patient perception of pain of the insertion (0-10 scale). In addition patient age, gender, height, weight, and body mass index were recorded.

A total of 18 useable subjects were enrolled with 6 subjects randomly assigned to the traditional group and 12 subjects to the ultrasound group. Analysis showed no significant difference between traditional and ultrasound techniques on minutes for insertion (11.3 ± 8.5, vs. 13.9 ±13.2, p=.670), patient pain perception (1.7±0.5 vs. 2.6±2.4, p=.227), or number of attempts (3.2 ± 2.5 vs. 1.7±.09, p=.204.). However, power was low at under .43 for all comparisons.

The results suggest that while ultrasound may require fewer attempts to cannulate, it is a potentially more painful and time consuming process.

Introduction

Intravenous (IV) cannulation is frequently an interventional technique performed by nurses and anesthesia providers for patients needing IV therapy for a variety of reasons. IV cannulation can be difficult to perform using the traditional landmark or visual/palpation technique in certain populations and may also contribute to a significant amount of pain when attempts to cannulate are numerous but unsuccessful. Alternative cannulation methods including limb dangling and warm compress wrapping, the application of nitroglycerin ointment to dilate veins, blood pressure cuff inflation, application of either an Esmarch bandage or a Rhys-Davies exsanguinator, and venous tourniquets typically have been employed to increase success rates of venous cannulations. Additionally, cutdown procedures, currently regarded as a method of last resort, are the oldest most direct method to reach uncommon venous sites. Ideally performed in operating suites or similar clinical settings, these have been used as a rescue technique to reach venous sites such as the inferior epigastric, intercostal, iliac, and lateral thoracic veins. The use of lidocaine as a local anesthetic injected subcutaneously has also been used to decrease pain associated with IV cannulation.[1-3]

Nurses and anesthesia providers continuously seek interventions to enhance treatment and improve the quality of care to patients, including IV cannulation. The use of ultrasound to place peripheral intravenous catheters in patients that are difficult to access has been researched and deemed efficacious.[4] Difficult to access patients encompass obese and renal dialysis patients, IV drug abusers, and sickle cell anemics. The purpose of this study was to compare the success rate, time to successful placement, number of attempts, and level of overall pain experience of IV catheter placement in the hand and forearm veins of adults. These adults presented with established difficult peripheral venous access, subsequently having either a traditional or ultrasound-guided method of IV cannulation used as a means of rescue.

Materials and Methods

After obtaining Institutional Review Board (IRB) approval, written informed consent was obtained from 22 subjects greater than 18 years of age. A power analysis revealed that 46 subjects (23

per group) were required for the investigation (power of 0.80 with an alpha of 0.05 and effect size = .84). Inclusion criteria included adults over 18 deemed a difficult intravenous (IV) cannulation secondary to two failed IV attempts by traditional cannulation methods. To ensure random assignment, 46 packets (23 with the traditional technique and 23 with the ultrasound technique) and all study materials, to include the consent and data collection tool with operational definitions, were shuffled, stacked, and then numbered consecutively 1 through 46.

Upon notification by the hospital unit(s) of a study candidate, a member of the research team selected a packet and proceeded with the appropriate intervention. The area for intervention was limited from the antecubital fossa to the wrist and the catheter size was limited to 18 or 20 gauges (Insyte, BD Medical, Sandy, UT). A research team comprised of three anesthesia providers trained in the use of the ultrasound device were responsible for providing the intervention and collecting the data. The data collection tool was designed by the researchers. It recorded time to cannulation, number of attempts to successful cannulation, size of catheter, site of insertion, and level of overall pain using the numerical rating scale (NRS). Researchers recorded patient height as well as weight and gender. Additionally, each anesthesia provider had demonstrated ultrasound expertise by having previously used the device as an aid in peripheral venous cannulation successfully five or more times. Ultrasound imaging was performed with the portable Site-Rite® 3 Ultrasound Unit (Bard Access Systems, Salt Lake City, UT) equipped with a 9.0 MHz probe.

Traditional Method

The provider applied a tourniquet to the upper arm and employed visual and/or palpation techniques to identify an appropriate vein for cannulation. Procedure start time was defined when the anesthesia provider began detecting potential vessels visually and/or by means of palpation. Having identified the vein, the provider cleansed the targeted area of skin with isopropyl alcohol 70 percent. One ml of 1% lidocaine was infiltrated intradermally and the catheter subsequently inserted at a thirty degree angle. Defined as advancement of the catheter into the vein followed by subsequent blood return,

successful IV cannulation was then determined by the anesthetist performing the procedure. Procedure stop time was defined as successful IV cannulation.

Ultrasound-Guided Method

Ultrasound guidance was used to perform needle placement under direct or real time so that the entire procedure was visualized continuously. A single operator performed the procedure. In similar fashion to the traditional method, a tourniquet was applied to the upper extremity. The transducer was placed on the skin and the target vessel identified and centered on the viewing screen—defining this as procedure start time. The skin was cleansed as with the traditional method, and local anesthetic was injected at a point corresponding to the middle of the ultrasound transducer. One ml of 1% lidocaine was used duplicating the traditional method. The cannula was advanced through the skin after anesthesia was achieved. Skin penetration complete, the operator viewed the ultrasound screen to visualize the venous puncture and subsequent advancement of the catheter. After the ensuing flash of blood into the catheter hub, the transducer was set aside and the procedure was completed as traditionally. Successful IV cannulation and procedure stop time were defined in duplicate of the traditional means. The failure of either technique, as in the success, was determined by the anesthesia provider inserting the catheter. In these instances timing continued until successful insertion was accomplished—each ensuing attempt duplicating the method used during initial insertion.

Statistical analysis was performed with the aid of a commercially available software package (SPSS 12.0.1 for Windows). Demographic data (age, gender, body mass index or BMI), size of IV catheter successfully cannulated, time to cannulation, number of attempts, and the rating of subjective pain was recorded. The mean of this data was calculated using descriptive statistics. The sample size had been determined using Cohen's table for one tailed t-test. With a power of .95 and an alpha of .80 it was determined that a sample size of 42 was needed. Three separate one tailed t-tests compared time to insertion, pain scores, and number of attempts between the traditional group and the ultrasound group as a means of rescue. Actual number of subjects in each group included one male and seven female subjects

in the traditional group, while the ultrasound group had six males and eight female subjects. All data was expressed as the mean ± standard deviation. A p-value of less than 0.05 was considered significant.

Results

The original sample size of enrolled subjects was 22 (n=22). Subjects rendered ineligible included a count of two secondary to broken randomization, and two due to unsuccessful cannulation. The resultant sample size (n=18) fell short of the 42 predicted by power analysis.

A total of 18 subjects completed the study, 6 randomly assigned to the traditional group and 12 to the ultrasound-guided group. Demographic data are shown in Table 1.

In both groups catheter sizes ranged from 18-20 gauges (See Table 2 for delineation.). Overall pain, time to insertion, and number of attempts regarding IV cannula placement did not differ significantly between the two groups (See Table 2.). Trends were noted, however, with all three variables. The mean pain score of the traditional method was 1.67 compared to that of ultrasound at 2.58 (p=0.277). The calculated mean for time to insertion of the traditional method was 11.33 minutes compared to ultrasound's mean of 13.52 minutes (p=0.623). Number of attempts approached significance with ultrasound having a mean of 1.67 and the traditional method a mean of 3.17 (p=0.204).

Discussion

Anesthesia providers are required to be highly skilled at intravenous cannulation. Obtaining the necessary pre-operative peripheral IV access in a difficult to access patient population often requires multiple attempts. Each failed attempt increases stress to patients and staff, possibly contributing to a negative effect on the impending anesthetic. Insertion methods based on the traditional approach of landmark/palpation can be painful, time consuming, and may result in arterial puncture, nerve damage, and paresthesias.[5] Other routes such as central venous or venous cut down cannulations are options, but not without the accompanying risks based on the unique invasive nature of each technique. Improving

the success rate of peripheral cannula insertion with ultrasound would elicit less stress with resultant increased patient satisfaction.

The attractiveness of the ultrasound device lies in the non-invasive nature of the apparatus. Along with its ability to pinpoint the position of reflecting internal surfaces, it also has the ability to produce real-time images of blood motion.[6] Despite its technologically advanced nature, the device does not emit ionizing radiation. Review of the literature supports the effectual use of ultrasound to increase the success rates for central line placement (including peripherally inserted central lines—PICCS), femoral catheterizations during cardiopulmonary resuscitation, and peripheral IV catheters in difficult access populations.[7-9] Successful IV cannulation is paramount during cardiac arrest, and Hilty et al. utilized ultrasound with greater success than the landmark technique while guiding femoral vein catheterization during cardiac arrest. A higher success rate (90% vs. 65%) and fewer attempts while utilizing the ultrasound device heralded this technique as a viable even preferable method during crucial times when vessel access becomes the determining factor for favorable resuscitative outcomes. This study also demonstrated that with ultrasound there not only exists less risk of arterial puncture, but a slightly faster time to cannulation than traditional cannulation methods.[7]

Ultrasound technology has enhanced placement of central catheters that have been inserted form the periphery as well. LaRue (2000) performed a 12 month retrospective study of 326 patients who had peripherally inserted midclavicular or central catheters placed using ultrasonography. Compared to the traditional landmark method with 431 catheters placed, ultrasound demonstrated a 42 % decrease in the number of needle penetrations needed to successfully cannulate and a 26% greater chance of successful cannulation of the vein on the first attempt.[9]

The use of ultrasound in IV cannulation as a rescue technique was first investigated using deep brachial or basilic veins as the target vessels. The ultrasound technique was employed after traditional

attempts at peripheral cannulation had failed. Keyes et al. investigated 101 adult patients presenting to the emergency department who had failed two or more unsuccessful attempts at peripheral IV cannulation via traditional means. Ultrasonic cannulation was successful 91% of the time. Of the unsuccessful 9%, the brachial artery was punctured in 2% of the subjects. One procedure was aborted secondary to severe pain, eight catheters infiltrated within one hour of cannulation, and in one morbidly obese patient the catheter was too short to cannulate the deep brachial vein. Seventy-three percent of the cannulations were successful on the first attempt with a mean time to successful cannulation of 77 $\pm$ 129 seconds (mean $\pm$ SD).[10]

Although efficacious as a rescue technique, potential complications of cannulating such deep vessels via ultrasound can preclude it as a first-line choice for long-term cannulation. Catheterizing more superficial vessels in the hand and forearm may be a better choice regarding decreased complications while maintaining the benefits of ultrasound guided catheter placement.

Aponte et al. investigated the use of ultrasound-guided cannulation as an aid to peripheral cannulation of veins of the hands and forearms. Although not as a rescue technique, the investigation compared the traditional method of obtaining IV access to that of the ultrasound method. The techniques were compared in relation to demographics, time to successful cannulation, number of attempts, and number of subjects where IV cannulation was successful on the first attempt. A total of 35 subjects with a documented history or suspicions of difficult IV cannulation were enrolled. No significant differences were noted between the groups in relation to any of the variables, however ultrasound was deemed as efficacious as the traditional method in subjects with a self-reported history of difficult IV cannulation or suspected difficult IV cannulation.[8]

Although ultrasound has been used for a wide array of clinical procedures, the Site-Rite® 3 is positioned to be an adjunct to a procedure of which the primary focus is vascular access, selected to meet

the needs of only vascular access—not those of diagnostic procedures.[11] Where once practitioners relied upon a sense of touch and knowledge of anatomy to guide them in placing a needle (traditional landmark method), practitioners can now observe the vessels beneath the skin's surface. Instead of replacing the provider's skills, the Site- Rite® 3 enhances them, enabling greater efficiency because the provider can now see what they are piercing. With ultrasound guidance, the vascular blindfold has been lifted.

Ultrasound not only unveils the position of the vein, it also indicates its patency. If the vein is thrombosed or of an unusually small diameter, the provider can choose another site without wasting time trying to access an implausible site.[11] The Site- Rite® 3 uses two-dimensional ultrasound, projecting the veins onto a monitor utilizing black and white imaging. It distinguishes arteries from veins by the compressibility of the image. Additionally, arteries are pulsating images unlike the stationary visage of the vein. The Site- Rite® 3 is compact and user-friendly, containing all of the components necessary for an ultrasound device to function properly.[11] (Figure 1).

Although the results of our study indicated that there was no significant difference between the two groups regarding any of the variables during cannulation as a means of rescue, one variable—that of number of attempts—appeared promising and did approach a value of significance. The trend indicated that with an adequate sample size, ultrasound might be deemed superior over the traditional technique regarding decreased number of attempts. The advantage of the ultrasound technique concerning this variable alone would justify its use as a first line adjunct in difficult to access patients during the peri-operative period. Decreased number of attempts would prevent additional stress and time to the patient pre-operatively, possibly decreasing the amount of pre-operative stress reducing the need for medication and its accompanying benefits.

Regarding the variables of pain and time to successful cannulation, the trend indicated that the ultrasound method required more time to complete and caused a greater amount of pain to the subjects.

Reasons proffered for these results include time needed to manage the non-standard IV equipment related to the ultrasound technique, and ultrasound's ability to cannulate deeper veins with the accompanying discomfort. Again, a more adequate sample size might refute the alleged trends.

Demographic data showed a higher mean of obese persons (BMI) across both groups indicating that this variable possibly comprises a greater percentage of the difficult to access population. Further studies with adequate sample sizes are again recommended to support this trend.

Four of the original 22 subjects were not successfully cannulated causing their disqualification from the study. Two subjects were disenrolled secondary to broken randomization after default to the ultrasound method was required based on a medically based increased urgency to obtain successful cannulation. Additionally, two more subjects were disenrolled because of the inability to cannulate.

Limitations to the study included lack of essential control over data collection. Initially, the investigators were differing in the manner of their timing of the procedure. Because of time constraints and limited personnel, the anesthesia providers placing the catheters were also the personnel collecting the data. Suggestions for future research of this nature include having someone from the primary investigative group overseeing all manner of data collection to ensure consistency and eligibility of the subjects.

Despite a clear delineation of what comprised a difficult "stick" in the study, the lack of skill consistency with initial cannulators may have interfered with the proper selection of a difficult to access population. For example, a novice may have tried the initial access twice without success, despite the subject possessing vasculature of normal anatomy. These subjects would then have been inadvertantly included in the study secondary to lack of skill of the initial cannulator. Ultrasound would be rendered superfluous in this instance since its adjunctive nature lies in its ability to find unseen veins—not easily

viewed ones. Future endeavors of this nature should provide a means of tighter jurisdiction over skill of the initial cannulators to control for this aspect of the process.

The biggest limitation of the study was the inability to procure an adequate sample size to support or disprove the null hypothesis. Recommendations for future studies of this nature would include expanding the pool of trained anesthetists who could operate the Site- Rite® 3 according to the operational definition for "expert". This would provide coverage for all shifts including weekends and nights without undue strain on the providers participating in the study.

Additionally, future investigations should ensure a separate pager or clearly defined means of reaching the researchers during any time and all shifts. This would prevent confusion regarding how to contact the researchers with potential study candidates, thus preventing loss of valuable contributions to sample size.

Future investigations should include children and infants in its subject population. Investigations should expand from venous cannulation to inclusion of ultrasound assisted peripherally inserted radial artery cannulation. Further investigation of overall pain experience is also recommended since a greater body of evidence would be needed to support such subjective experience.

An incidental finding reported in the Aponte et al. study was the visibility the study brought to the ultrasound guided technique of IV cannulation.[8] This current investigation continued to provide press for the ultrasound technique at the conducting facility, inciting visions of expanding its use to other forms of cannulation such as for arterial access.

Ultrasound continues to be a potentially useful adjunct in placing peripheral IV catheters in the veins of the wrist and forearm, particularly as a rescue technique and pre-operatively for patients intended to undergo anesthesia. It can preclude the awkward placement of antecubital fossa IVs and central line placements in pre-operative patients to whom it may cause discomfort, stress, and increased precarious

side effects. Repeat investigations continue to be encouraged to not only support the efficacy of this method, but also to disseminate awareness of this procedure as a possibly more desirable means of obtaining peripheral IV access.

Figure 1. Diagrammatic schema of basic ultrasound scanner.

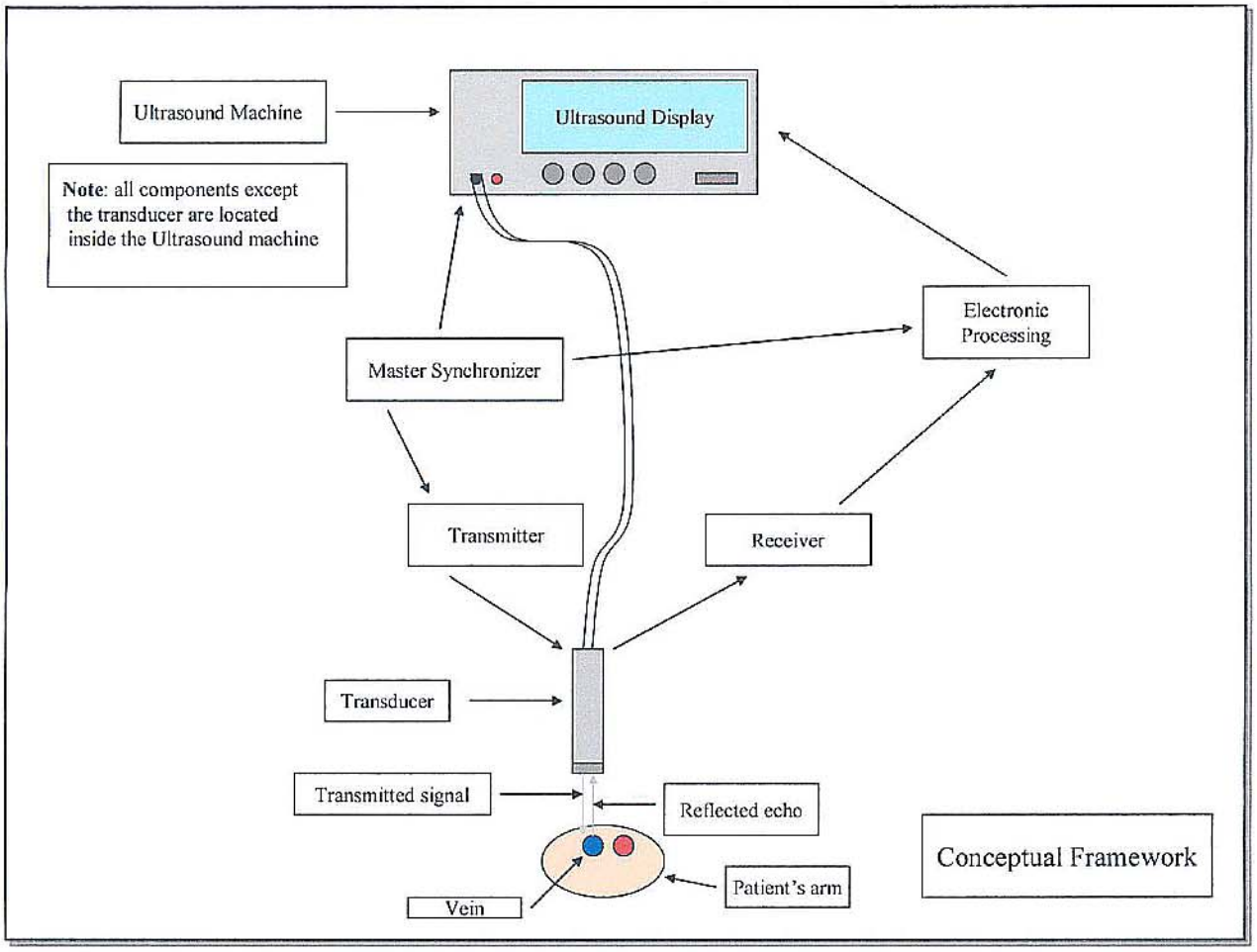

Table 1. Demographic data of 22 original subjects

	Traditional Group	**Ultrasound Group**
Time to insertion	12.25±15.2	16.31 ± 9.08
Gender	Male = 1 Female = 7	Male = 6 Female = 8
BMI	39.2 ±13.6	36.0 ±7.3

Data are given as mean ± SD, except for gender, which is given as number of subjects.
The ultrasound group included 14 subjects and the traditional group included 8 subjects.

Table 2. Comparison of IV catheter gauge of successful cannulation, time to successful IV cannulation, number of attempts per subject, number of subjects, and rating of overall pain experience.

	Traditional Group	***Ultrasound Group***	**p value**
Location of successful cannulation	Hand = 3 Forearm = 2 Antecubital =1	Hand = 1 Forearm = 4 Antecubital = 7	--
Size of IV catheter of successful cannulation (ga)	18 ga = 3 20 ga = 3	18 ga = 8 20 ga = 4	--
Time to successful IV cannulation, (minutes)	11.3 ± 8.5	13.9±13.2	0.670
Number of attempts per subject	3.2±2.5	1.7 ± 0.09	0.204
Overall pain experience (NRS)	1.7±0.5	2.6±2.4	0.227
*NRS 1-10; 1 = least, 10 = most			

Data are given as mean ± SD. *NRS (Numerical rating scale)

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Short Biographical Sketch

Major Nancy Pappas, SRNA, BSN, NC, USAF, Captain Terese Michaud, SRNA, BSN, NC, USAF, Captain James Steward, SRNA, BSN, NC, USAF and Captain Russell Wolbers , SRNA, BSN, NC, USAF were nurse anesthesia students, Nurse Anesthesia Program, Graduate School of Nursing, Uniformed Services University of the Health Sciences, Bethesda, MD while conducting this study. They completed Phase II Clinical Training at Wright-Patterson Medical Center at Wright-Patterson AFB, OH.

LTC Bruce Schoneboom was the program director of the nurse anesthesia program during the course of the research. He is currently deployed. Dr. Dorraine Watts is an Associate Professor of Nursing, Graduate School of Nursing, Uniformed Services University of the Health Sciences.

Major Timothy Samolitis was the Assistant Clinical Site Director, Nurse Anesthesia Clinical Training, Wright-Patterson AFB, OH and Adjunct Assistant Professor, Graduate School of Nursing, Uniformed Services University of the Health Sciences. He is now retired.