Real-Time Ultrasound–Guided Femoral Vein Catheterization During Cardiopulmonary Resuscitation

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Study objective: To compare the use of real-time–ultrasound guidance with the standard landmark-oriented approach for obtaining femoral vein catheterization in patients requiring intravenous access during CPR.

Methods: Prospective, randomized, paired subject–controlled clinical trial in the setting of an urban teaching county hospital emergency department. The study comprised a convenience sample of 20 patients presenting with apnea and pulselessness in the ED. Each patient received bilateral femoral lines, one by ultrasound guidance and one by the landmark approach (control). Randomization determined which technique and which side would be attempted first. The following parameters were recorded: time to initial flash of blood, time to completion of catheterization, number of needle passes, and rate of arterial catheterization. CPR and Advanced Cardiac Life Support protocols were continued during both procedures.

Results: Real-time ultrasound–guided catheterization had a higher success rate (90% versus 65%, P = .058), a lower number of needle passes (2.3±3 versus 5.0±5, P = .0057), and a lower rate of arterial catheterization (0% versus 20%, P = .025) than the standard landmark-oriented approach. Ultrasound was also slightly faster in time to blood flash and in time to catheterization. An incidental finding of interest was that real-time ultrasound demonstrated the presence of femoral vein pulsations during CPR.

Conclusion: Real-time ultrasound–guided femoral vein catheterization was faster and produced a lower rate of inadvertent arterial catheterization and a higher rate of success during CPR than the standard landmark-oriented approach. Also, ultrasound demonstrated that palpable femoral pulsation during CPR is venous rather than arterial.

INTRODUCTION

Central IV access is a relatively common procedure in the emergency department. Emergency physicians rely on their skill to establish a central line as a lifesaving procedure for delivery of critical care medications, for volume resuscitation with saline or blood products, and for central cardiac monitoring and pacing. The success rate, the time to completion, and the rate of complications are all important aspects of this procedure.

Ultrasound-guided IV catheterization in the ED is an emerging application of real-time ultrasound technology but has received little representation in the literature. Studies done in an ICU or operating room environment have proved its efficacy for the establishment of internal jugular catheterization using the Seldinger technique. Although ultrasound guidance may be as useful in the emergency room as in the operating room for the establishment of internal jugular catheterization, its use has not been studied in catheterization of the femoral vein, which is also commonly attempted, especially during CPR. Typically, in patients with strong femoral arterial pulses, a landmark-oriented approach to femoral vein catheterization using the Seldinger technique is very successful. However, in patients with low blood pressure or no palpable pulse, this approach becomes more difficult and is prone to a higher rate of failure and complication. We hypothesized that use of ultrasound to visualize the femoral vein and artery and to guide catheterization of the femoral vein would improve the success rate of venous catheterization and decrease the rate of arterial catheterization in the setting of cardiopulmonary arrest.

MATERIALS AND METHODS

We used a convenience sample comprising serial patients who presented in cardiopulmonary arrest to the ED at Highland General Hospital when either of two investigators (WH or PH) was present. CPR and resuscitative efforts following the Advanced Cardiac Life Support protocol were directed by an attending physician or other senior emergency medicine resident to allow the study investigators to focus on the establishment of femoral venous access. This study was approved by the Highland General Hospital Institutional Review Board.

Historical, demographic, and physical examination information was recorded for each patient. Bilateral femoral venous lines were placed in each patient by a single investigator (WH or PH) using a standard Seldinger technique. One femoral line was inserted by the landmark-oriented technique using a CPR-generated pulse (if present) or an estimate of the point midway between the anterior superior iliac crest and symphysis pubis; the other was inserted with real-time ultrasound guidance. In this way, each patient served as his or her own control. A computer-generated randomization chart predetermined the choice of initial technique (landmark versus ultrasound) and the initial side (left versus right).

Time was recorded beginning at the point at which the ultrasound machine was turned on and in position at the bedside, two femoral line catheterization kits were open, the bilateral groin area had been swabbed with povidone-iodine, and sterile gloves were on the investigator. The time to flash of blood by the finder needle, the time to completion (i.e., functional catheter placement), and the number of needle passes required to obtain blood were recorded. If the investigator was unable to get any flash of blood after 15 needle passes on one side, the attempt was discontinued and the procedure was considered unsuccessful.

The real-time ultrasound-guided technique was performed with an Aloka 650 CL ultrasound machine and a 7.5-MHz linear array probe. To maintain semisterile technique, the probe was swathed in povidone-iodine and sterile ultrasound gel was applied to the probe surface. Glutaraldehyde immersion was used to sterilize the probe between procedures. The investigator held the probe with one hand, located the dark hypoechoic vein and artery, centered the probe over the medial vessel (femoral vein), and then inserted the finder needle under the middle of the probe with the free hand. Once a flash of blood was encountered, the ultrasound equipment was removed and standard Seldinger technique was followed.

After completion of both sides, ultrasound was used to confirm line placement in bilateral veins. Because detection of a thin plastic catheter inside of a vessel can be technically difficult (it leaves a thin echoluent shadow and only rarely can be visualized directly in the vessel), confirmation of line placement was made by moving the stiff 8F catheter in an anterior and posterior direction and visualizing real-time concurrent motion in the cannulated vessel and not in the adjacent noncannulated vessel.

Success was defined as placement of a functioning line in the femoral vein. Failure was defined as an inability to place a functioning catheter in the femoral vein. Failures comprised inadvertent arterial catheterizations, subcutaneous tissue catheterizations, and attempts abandoned after 15 unsuccessful passes of the finder needle.

Ultrasound training specific to this procedure was informal. The two investigators were emergency medicine residents in postgraduate years 3 (WH) and 4 (PH) who had undergone 2 to 3 hours of residency-directed ultrasound didactic instruction and had become adept at sterile ultra-
sound-guided internal jugular vein catheterization (6 to 10 catheterizations each) through self-teaching before the beginning of this investigation. In addition, as recorded in the Highland resident procedure log database, each investigator had placed 15 to 20 femoral lines by the landmark-guided technique and had supervised the placement of 10 to 15 landmark-guided femoral lines by interns and junior residents. Both investigators had performed only one ultrasound-guided femoral venous cannulation before entry of study patients.

Statistical analysis was performed using Statview SE 5.0 and graphics (Abacus Concepts, Incorporated). Continuous data were reported as mean and standard deviation and were compared between techniques with the use of a two-tailed, paired Student’s t test. Categorical data were reported as frequencies and were compared between techniques by means of McNemar’s test. A probability value of less than .05 was considered statistically significant.

RESULTS
Twenty patients completed the study protocol. No patients had femoral scars from previous surgery or use of injection drugs. None of the study patients survived to hospital discharge. The mean age of study patients was 64±15 years (range, 30 to 82 years). Thirteen were men and seven women. Average weight was 76.3 kg (range, 50 to 160 kg). Average height was 170.9 cm.

The Table summarizes the results of the 20 ultrasound-guided and 20 landmark-oriented catheterizations. Of the seven failures by landmark technique, three resulted from an inability to get a flash of blood, and four were arterial catheterizations. In addition, ultrasound guidance was used on one occasion to achieve access on the landmark-oriented side after multiple attempts to find the femoral vein failed. There was no apparent trend toward increased speed or improved rate of success with ultrasound as the study progressed. Of the two failures by ultrasound, one was caused by an inability to get a flash of blood, and one was a non-functioning catheterization (the line was later observed ultrasonographically in the subcutaneous tissue directly overlying the vein).

Eight of the 20 patients had no palpable pulse with CPR. Nine patients catheterized by one author (WH), two of whom had no palpable pulses, were observed to have ultrasonographically visible femoral venous pulsation without visible femoral artery pulsation during CPR.

DISCUSSION
Femoral vein catheterization in the ED is a useful technique for the administration of fluid, blood products, and medications and for limited central venous monitoring. Its application has been studied in trauma, in critically ill patients, in comparison with saphenous vein cutdown, in subclavicular and internal jugular vein catheterizations, and in CPR. Many studies have touted its usefulness and accessibility. The scope of reported complications with femoral line catheterization includes deep venous thrombosis, inadvertent arterial catheterization, hematoma, soft-tissue injury or subsequent infection, and arteriovenous fistula.

Getzen and Pollak, in 1979, reported a 95% success rate for femoral venous catheterization in a large series of military casualty victims. In 1988, Mangiante et al reported a success rate of 94% during trauma resuscitation, with saline flow rates of 1.622 mL/min through a large-bore femoral catheter. Westfall et al reported in 1994 that femoral catheter placement during trauma resuscitation was faster than saphenous vein cutdown, allowed for a quicker saline solution infusion time, and had a similar low (2.5%) rate of complications. Only patients with a palpable femoral arterial pulse were included in the Westfall results, however, and the authors concluded that the absence of an arterial pulse may affect the success rate of femoral vein catheterization.

Table. Determinants of successful catheterization.

<table>
<thead>
<tr>
<th>Measured Result</th>
<th>Ultrasound-Guided</th>
<th>Landmark-Guided</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. successes/no. patients</td>
<td>18/20</td>
<td>13/20</td>
<td>—</td>
</tr>
<tr>
<td>% Successes (95% CI)</td>
<td>90 (77–100)</td>
<td>65 (50–75)</td>
<td>.058</td>
</tr>
<tr>
<td>Time to flash of blood (mean±SD)</td>
<td>33±5±5</td>
<td>33±5±5</td>
<td>.0001</td>
</tr>
<tr>
<td>Time to catheterization (mean±SD)</td>
<td>121±60±90</td>
<td>124±64±9</td>
<td>.0001</td>
</tr>
<tr>
<td>No. attempts (mean±SD)</td>
<td>2.3±3</td>
<td>5±5</td>
<td>.0057</td>
</tr>
<tr>
<td>No. arterial catheterization (%)</td>
<td>0/6</td>
<td>4/20</td>
<td>.025</td>
</tr>
</tbody>
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Jastremski et al.12 studied femoral vein catheterization in 1984, with a success rate of only 69% during CPR. Sessler and Glauser17 reported a 75% success rate for femoral catheterization but included patients in cardiac arrest or in profound shock. Emerman et al.14 restudied this issue in 1990 and reported a higher success rate with subclavian vein catheterization (94%) than with femoral vein catheterization (77%) during cardiac arrest. They reported arterial catheterization in 6.0%, femoral catheter placement into the soft tissue in 8.5%, and an inability to pass the catheter in 8.5% of the 47 attempted femoral vein catheterizations. Swanson et al.13 reported an 89% success rate, but only one third of their patients were undergoing CPR and no subset analyses were provided.

Our approach to real-time ultrasound-guided central vein catheterization evolved from experience with internal jugular vein catheterization. The first report of combined real-time ultrasonographic imaging and internal jugular catheter placement was by Yonei et al.3 in 1986. They used a sterile 5-MHz probe to identify the internal jugular vein and carotid artery during placement of internal jugular catheters and successfully catheterized 160 patients without complication or failure.

In 1990, Mallory et al.4 published the first controlled study comparing conventional and ultrasound-guided internal jugular vein catheterization. They found that real-time ultrasound imaging decreased the failure rate and the mean number of passes and was useful in the successful catheterization of all of their patients who could not be catheterized by conventional techniques. A larger, controlled comparison study was published in 1993 by Denys and Reddy6 and again looked at internal jugular vein catheterization. Results included significantly higher success rates, a lower number of needle passes, and lower complication rates with ultrasound guidance.

The literature describes the usefulness of ultrasound in the localization and study of femoral venous anatomy, particularly with respect to compression ultrasound for deep venous thrombosis,18 and in arterial catheterization for diagnosis and treatment of catheter-induced aneurysms.19 However, no data have been published regarding the use of ultrasound guidance for femoral vein catheterization, presumably because of the ease of performance of this procedure during normal physiologic states. However, the application of this technology for femoral vein catheterization in difficult patients seems imminent.

Our results indicate that direct visualization of the femoral artery and vein with real-time ultrasound reduces the problems associated with femoral vein localization and catheterization during CPR. We found a higher success rate (approaching statistical significance) with the use of ultrasound localization and real-time guidance compared with the traditional landmark-oriented approach, which relies on the palpation of femoral pulses or is based on bony anatomy in the absence of pulses. Our success rate of 90% with the use of ultrasound is comparable to that achieved

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Figure 1.

Ultrasound image of left groin during CPR compression with large, hypoechoic (dark) femoral vein to the left of the smaller, hypoechoic femoral artery.

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Figure 2.

Ultrasound image of left groin in same patient seconds later, during relaxation phase of CPR. Femoral vein to the left of the artery is markedly reduced in size, whereas arterial diameter is visually unchanged.
with other nonfemoral (subclavian or internal jugular) central vein catheterizations in the CPR setting.\textsuperscript{5,14}

With the landmark approach, our success rate for femoral vein catheterization during CPR was 65\%, consistent with the rates reported by others.\textsuperscript{12,14} Our 20\% rate of arterial catheterization with the landmark technique during CPR is between the published rates of 6\% and 31\%.\textsuperscript{12-14}

Although they were statistically significant, the differences in time to flash of blood and time to catheterization appeared to be of minimal clinical significance in relation to the importance of successful establishment of venous access. Clearly, the use of an ultrasound probe in experienced hands does not add time to an already expedient procedure.

One possible explanation for the difference in success rate between ultrasound-guided and landmark-oriented approaches comes from an observation made during our study. First, visual location of the vein by ultrasound excludes the need to palpate a femoral pulse, which could not be located in 40\% of our study patients. Second, when it is present, the pulsation that is palpable in the femoral sheath region of the groin during CPR does not appear to arise from the femoral artery, even with the application of aggressive chest compressions. This pulsation can be visualized by real-time ultrasonography as a markedly changing femoral vein diameter during compressions without appreciable change in the diameter of the artery (Figures 1 and 2). In normal physiologic conditions (non-CPR), the opposite is seen: ultrasound demonstrates pulsations in the arterial diameter, but the vein diameter remains constant (the venous diameter enlarges only with prolonged Valsalva maneuver).

The concept that femoral pulses during CPR are venous rather than arterial has been suggested previously. Coletti et al.\textsuperscript{20} selectively cross-clamped proximal femoral veins and arteries during CPR in a canine model. They noted that in all cases the palpated femoral pulse was lost after clamping of the vein, whereas the pulse was preserved after cross-clamping of the femoral artery. The investigators then catheterized both femoral vessels and noted that CPR generated pulse waves of equal magnitude in the vein and in the artery. Several dog and human studies also have found comparable arterial and venous mean systolic pressures during CPR.\textsuperscript{21-23} In 1994, Connick and Berg\textsuperscript{24} reported the presence of palpable pulses in the femoral region during open-chest cardiac massage in humans with cross-clamped aortas. They noted that this finding may affect the success of femoral vein catheterization during CPR, commenting that attempts to catheterize medial to the femoral pulse during chest compressions may result in catheter placement medial to the vein.\textsuperscript{24}

After observing the presence of venous pulsations in the first several patients catheterized, one author (WH) began directing the needle over the pulsation during the landmark-guided technique; the other author (PH), who did not make this observation, completed the study using the standard landmark technique (ie, inserting the finder needle medial to the pulse). The average time to flash of blood for the former author using the landmark technique was 64.3 seconds (range, 13 to 74 seconds) for the first four patients, but only 9.8 seconds (range, 2 to 15 seconds) for the last five patients. This trend, although not statistically significant, was not observed for the second investigator. Perhaps pressure waves from chest compressions transmit pulses more easily through the thinner, distensible vein walls than through the thick, muscular arterial walls of the femoral vasculature. Real-time ultrasonography clearly demonstrates these venous pulsations and confirms the finding that the palpated pulse is venous.

The observation of femoral venous wall pulsations during CPR implies that new techniques are needed for femoral vein cannulation during chest compressions and raises questions regarding human physiology and the administration of medications in the setting of impaired lower extremity vascular flow\textsuperscript{25,26} during CPR. We advise caution and believe that further investigation is needed to determine the complication (arterial puncture) rate before direction of the needle over the site of femoral pulsation during CPR can be advocated. Clearly, a miss with the finder needle placed medial to the femoral vein allows for potential successful redirection laterally, and this carries lower morbidity to the patient than does striking the femoral artery, particularly if the patient becomes coagulopathic.

Several potential limitations to the application of this study need further review. First, the sample size is small. Statistical significance was achieved in serial end-point measurements. The success rate between groups achieved a probability value of .058 in comparative analysis. This result, along with the fact that there was no overlap between the 95\% CIs, indicates that a true difference probably exists between success rates. However, the means, variances, and frequencies found in this study may differ from the true population values.

Second, the bias of the investigators was favorable toward ultrasound guidance. We attempted to limit any effect of this bias by randomly determining which technique was attempted first. The establishment of IV access was a crucial step in the ED resuscitation of each patient, and there was

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pressure to achieve success with whichever technique was used first.

Third, the two primary investigators performing the catheterizations in this study have a developed interest and experience with the use of ultrasound. We chose to limit the number of investigators so as to limit the variance. Because it is difficult to quantify the clinical and educational experience of individual physicians, it may be difficult to extrapolate our success rates until the use of ultrasound is more widespread among emergency physicians.

Ultrasound guidance is a practical solution for vascular access in situations in which normal techniques have proven limitations. It is an excellent adjunct to strong technical skills and will undoubtedly be applied to an increasing number of procedural dilemmas. Real-time ultrasound-guided femoral vein catheterization during CPR appears to be more successful, to have a lower rate of arterial catheterization, and to be slightly less time-consuming than catheterization with the traditional landmark-oriented approach. Ultrasound guidance allows use of the femoral vein for quick central IV access during cardiac arrest with a success rate approaching that of landmark-oriented techniques for cannulation of other, more proximal central veins. Real-time ultrasound-guided vascular access is a useful procedure in the ED and should be included as part of the standard curriculum for emergency physicians.

REFERENCES
Brief Commentary

The authors of this preliminary report are the first to examine the use of ultrasound for femoral vein catheterization in the emergency department patient. Its multiple methodologic shortcomings (well described by the authors) are less important than the concept that an era of ultrasound-guided ED procedures may soon be at hand.

Although it may be difficult to imagine how several procedures (including foreign-body removal, suprapubic aspiration, pericardiocentesis, and jugular cannulation) would not be expedited with ultrasound guidance, rigorous proof in a clinical setting is fraught with technical considerations, and it is difficult to establish statistical superiority over standard (ie, blind) techniques that are already quite successful.

The first studies of such ED uses have all lacked optimal equipment such as Doppler technology, needle guides, color flow, standoff transducers, and ultrasound-visible needles. Nonetheless, the findings are at least moderately positive and should stimulate further research by emergency physicians who have incorporated ultrasound into daily practice.

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