A Prospective Comparison of Ultrasound-guided and Blindly Placed Radial Arterial Catheters

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Abstract

**Background:** Arterial cannulation for continuous blood-pressure measurement and frequent arterial-blood sampling commonly are required in critically ill patients.

**Objectives:** To compare ultrasound (US)-guided versus traditional palpation placement of arterial lines for time to placement, number of attempts, sites used, and complications.

**Methods:** This was a prospective, randomized interventional study at a Level 1 academic urban emergency department with an annual census of 78,000 patients. Patients were randomized to either palpation or US-guided groups. Inclusion criteria were any adult patient who required an arterial line according to the treating attending. Patients who had previous attempts at an arterial line during the visit, or who could not be randomized because of time constraints, were excluded. Enrollment was on a convenience basis, during hours worked by researchers over a six-month period. Patients in either group who had three failed attempts were rescued with the other technique for patient comfort. Statistical analysis included Fisher’s exact, Mann-Whitney, and Student’s t-tests.

**Results:** Sixty patients were enrolled, with 30 patients randomized to each group. Patients randomized to the US group had a shorter time required for arterial line placement (107 vs. 314 seconds; difference, 207 seconds; \( p = 0.0004 \)), fewer placement attempts (1.2 vs. 2.2; difference, 1; \( p = 0.001 \)), and fewer sites required for successful line placement (1.1 vs. 1.6; difference, 0.5; \( p = 0.001 \)), as compared with the palpation group.

**Conclusions:** In this study, US guidance for arterial cannulation was successful more frequently and it took less time to establish the arterial line as compared with the palpation method.

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guidance to radial-arterial cannulation to determine whether it offers advantages over the traditional palpation technique in a critical-care setting. The hypothesis of this study was that there is no difference between the two techniques in time to successful cannulation, number of attempts before successful placement, and the number of puncture sites used per patient.

**METHODS**

**Study Design**
A prospective, randomized study design was chosen. The institutional review board approved the study with written informed consent waived because of the patient requirement for arterial cannulation and because of evidence that US guidance is desirable in vascular-access procedures. In addition, no patient-identifying information was collected.

**Study Setting and Population**
The study was performed in the ED of an urban, tertiary-care facility with an annual volume of 78,000 patients. The facility supports an emergency medicine residency-training program and is a Level 1 trauma center. Hospital US credentialing, on the basis of the American College of Emergency Physicians guidelines, is available to all attending emergency physicians who meet the criteria. Ultrasound credentialing includes a total of nine US applications, and the credentialing package is all in one. Vascular access is a part of the credentialing package. All residents and faculty receive regular emergency US didactic and hands-on training that includes US-guided peripheral and central venous cannulation. Until the beginning of this study, arterial lines were not placed under US guidance in the ED.

All patients 18 years of age or older who were deemed to require an arterial line by the treating attending emergency physician were eligible for study enrollment. The indications for arterial cannulation included the patient’s need for continuous blood-pressure monitoring, frequent blood-gas analysis, and placement of the patient on vaso-active medications. Patients with previous attempts at arterial cannulation during the same ED visit as well as any unstable patient in whom an arterial line had to be placed before study randomization were excluded.

**Study Protocol**
Each patient included in the study was randomly assigned to either the US-guided or palpation-technique group by using a random-number generator. Randomization results with a data sheet were kept in a sealed envelope in a locked and secured area. Randomization results and data sheets were removed one at a time. Patients were entered on a convenience basis when one of four researchers was available. Researchers’ work hours encompassed all hours of the day and days of the week.

For this study we selected four US-credentialed attending physicians. None of the four had previously placed US-guided arterial catheters, but all had experience placing US-guided peripheral and central venous lines. Three of the four physicians are authors of this article. Further, each of the four researchers had placed more than 50 arterial lines by the traditional palpation method.

A standard 20-G Arrow radial-artery catheterization kit (Arrow International Inc., Reading, PA) was used for all access procedures. The palpation technique was performed according to standard practice, by using the radial-artery pulsation as a guide to placement. The US technique consisted of applying the transducer to the skin and using the US image to locate the target vessel. No palpation was allowed in the US-guided group. The artery was identified by lack of compression, in comparison to any nearby veins and power Doppler if needed. In addition, the radial artery typically has visible pulsations at this resolution.

Both the palpation technique and US-guided technique were performed in sterile conditions, with a sterile cover and gel used for the US transducer. Ultrasound-guided artery cannulation was achieved in the long axis. Direct visualization of the guide wire feeding into the artery was possible and assured correct placement.

Because of the possibility for numerous attempts at arterial cannulation, which can occur in some difficult patients, we elected to limit access attempts in each group to three completely new attempts per patient. Each attempt was defined as a new and purposeful penetration of the skin with the needle, followed by an unlimited number of redirections under the skin, as needed. A new kit was not required for each new attempt if the catheter being used never found the artery and was not filled with blood. If failure to successfully place an arterial line occurred when using the technique to which the patient was randomized, the other technique was used as a rescue technique. Physicians also kept track of how many different sites they used. A new site entailed moving to the other wrist or another backup location, such as the brachial artery, if all possibilities at the first site were used. One anatomic site could be the site of all three attempts. Complications were noted for each patient. Potential complications included major complications, such as arterial laceration or thrombosis. Hematoma development, defined as an obviously visible accumulation of subcutaneous blood after arterial penetration, was noted to be a minor complication.

**Measures**
Study physicians used a SonoSite Ilook 25 (Bothell, WA) US machine with a 5–10 MHz linear array transducer. An observer timed with a stopwatch how long a physician took to achieve successful placement. In the US group, time zero was defined as the time at which the US machine was turned on before gel was placed on the transducer and it was covered with a sterile glove. No patient information could be entered on this unit. For the blinded approach, time zero was defined as the time at which the operator’s fingers were placed on the wrist to palpate the radial pulse and to guide needle placement. The time of the placement was ended when the wire was fed into the artery and a catheter was successfully placed over the wire into the vessel, with appropriate pulsatile blood flow returned. Data were collected by using a standardized data sheet.

**Data Analysis**
Data were analyzed by using a commercially available software package, StatsDirect (Sheffield, UK). Sample-size
calculations were based on observations of the time required for traditional palpation-placed arterial lines. Comparison of successful placement rates on first attempt between the US-guided and palpation group was made by using Fisher’s exact test. The Mann-Whitney test was used to compare the number of attempts required to successfully place an arterial line and the number of anatomical sites used. Time to successful placement was compared by using the Student’s t-test after normality and variance were assessed.

RESULTS

A total of 60 patients were enrolled into the study over a six-month period, with 30 randomized to the palpation group and 30 to the US-guided group. Indications for arterial cannulation, heart rate, and intubation status are found in Table 1. The two groups did not differ significantly in blood pressure (Table 2). Thirteen (22%) patients in the study had a systolic blood pressure below 100 mm Hg. Six of these were in the US-guided group, and seven in the palpation group. Eleven (37%) patients in the palpation group required rescue with US guidance. None of the patients in the US-guided group required more than two attempts, and none were switched to the palpation technique for rescue. An arterial line was placed on the first attempt in 26 of 30 (87%; 95% confidence interval [CI] = 74% to 99%) patients in the US-guided group versus 15 of 30 (50%; 95% CI = 31% to 69%) in the palpation group (p = 0.005 difference of 37% [95% CI = 14% to 59%]). There were a total of 36 attempts at arterial-line insertion in the US group, versus 65 attempts in the palpation group. Half of all palpation-group patients (15/30, 50%; 95% CI = 31% to 69%) developed a hematoma at a site of insertion or attempted insertion. Only 2 of 30 (7%; 95% CI = 0 to 16%) patients in the US-guided group developed a hematoma.

The US-guided group showed significantly shorter time to successful arterial cannulation, fewer cannulation attempts, and fewer numbers of anatomical sites used (Table 3). All four study physicians entered data points into each group. For the US-guided group, the physicians placed 6, 10, 6, and 8 lines in the palpation group, whereas the same physicians placed 5, 10, 8, and 7 lines, respectively. Time to successful line placement was compared by using the Student’s t-test after normality and variance were assessed.

DISCUSSION

Ultrasound guidance for central-line placement is rapidly becoming common, with many reports and medical societies supporting its use for all centrally placed venous catheters.1–4 A small, but growing, body of literature is supporting the use of US guidance for placement of peripheral lines in difficult-access patients.5–7 This allows patients to avoid a central line who would have received one simply for the sake of access. Surprisingly little has been written about US guidance for placement of arterial lines, a procedure that may be difficult and time consuming and can have both major and minor complications such as hematoma or arterial laceration. Arterial lines may be required in critically ill patients in a variety of settings, including the ED, the perioperative setting, and ICUs. These patients may require close monitoring of blood pressure with vasoactive medication, intravenous fluid administration, or intravenous antihypertensive regimens, among other reasons. As the number of critical-care patients increases as a result of rising acuity and full hospital beds, more arterial lines likely will be placed in the ED and ICU settings.

In recent years, not only has the increasing age and worsening health of the general population burdened the health system, but pivotal studies have suggested an aggressive approach to the resuscitation of critically ill patients, such as those who were found to be septic.8 Continuous-pressure monitoring has been shown to play a key role in fluid and pressor resuscitation of septic

<table>
<thead>
<tr>
<th>Parameter</th>
<th>US-guided (n = 30)</th>
<th>Palpation (n = 30)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean heart rate in beats/min (± SD)</td>
<td>86 (±23.1)</td>
<td>82 (±19.7)</td>
<td>4 (±3.4)</td>
</tr>
<tr>
<td>Number of patients intubated</td>
<td>22</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>Number of patients requiring continuous BP monitoring</td>
<td>17</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Number of patients requiring frequent ABG sampling</td>
<td>25</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>Number of patients requiring repeated blood laboratory analysis</td>
<td>8</td>
<td>9</td>
<td>1</td>
</tr>
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BP = blood pressure; ABG = arterial blood gas.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>US-guided</th>
<th>Palpation</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean time to success, in s (range)</td>
<td>107 (50–380)</td>
<td>314 (20–1,200)</td>
<td>207; p = 0.0004</td>
</tr>
<tr>
<td>Median time to success, in s</td>
<td>80</td>
<td>208</td>
<td>128</td>
</tr>
<tr>
<td>Number of attempts (mean)</td>
<td>1.2</td>
<td>2.2</td>
<td>1; p &lt; 0.001</td>
</tr>
<tr>
<td>Number of attempts (median)</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sites used (mean)</td>
<td>1.1</td>
<td>1.6</td>
<td>0.5; p = 0.001</td>
</tr>
<tr>
<td>Sites used (median)</td>
<td>1</td>
<td>1</td>
<td>0</td>
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</tbody>
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patients and is part of critical-care pathways responsible for a significant improvement in patient outcome. Thus, the work of placing an arterial line is well rewarded by the most important measure: contribution to increased patient survival.

The earliest report on US-guided arterial cannulation occurred in 1989 and described the application of continuous-wave Doppler to aid in cannulation.13 Those investigators actually used a continuous-wave Doppler probe identical to that used for detection of pedal pulses or fetal heart rates. Despite not having actual real-time visual guidance, the investigators successfully placed 11 of 12 arterial lines. The other report of US-guided arterial cannulation in adults was published by Levin et al. in 2003.10 The investigators showed that the use of B-mode US decreased the rate of catheter-insertion failure on the first attempt as well as decreasing the total number of attempts required to place the catheter.10 This study was performed by anesthesiologists in a perioperative setting. The researchers enrolled a total of 69 patients into either traditional or US-guided arterial cannulation approaches. These were stable patients, and none were reported to be hypotensive or have difficult to palpate pulses. The investigators reported a significantly higher first-attempt success rate for US-guided lines (62% vs. 34%; p = 0.03).

Although Levin et al.10 believed that US was a useful adjunct to arterial cannulation in stable perioperative patients, there are some limitations in applying their data directly to critically ill patients. First, hypotensive patients who are regularly encountered in the ED may be even more difficult for line placement, and it is unclear whether US would significantly improve this. Further, the US device used by the investigators imaged at 4 MHz, which is too low a frequency for such superficial work. It is possible that had they used a higher frequency US machine, they would have had no failures in the US group and a significant decrease in the time to arterial cannulation for the US-guided approach. Studies in the pediatric anesthesia literature also confirm the utility of arterial guided cannulation in the stable peri-operative setting.11,12

Our study, which used a 5–10 MHz linear transducer, revealed a statistically significant decrease in the time to successful arterial cannulation for the US-guided group compared with the palpation group. The number of attempts at line placement was significantly lower in the US-guided group, which likely reduced discomfort for patients and the rate of complications. Although our primary objective was to detect a difference in the time to successful arterial cannulation, this is not the most clinically relevant finding of our study. The most significant difference was the greater likelihood of first-pass success when US guidance was used for arterial cannulation. Because arterial cannulation can cause significant pain and distress to our patients, it is the lower rate of repeating the procedure at another site that makes the greatest clinical difference.

Ultrasound rescue was required in 11 patients in the palpation-placed group in our study. However, none of the US-guided group’s patients required more than two attempts, obviating the need for a rescue technique. The failure rate of blindly placed lines may have been higher in our study than in the Levin et al.10 report for two reasons. First, we believed that making rescue available for each group was critical for patient comfort and safety, and it is possible that if physicians were allowed to try indefinitely, more lines eventually would have been placed in the palpation group. Second, 22% of our patients were hypotensive, with systolic blood pressure of less than 100 mm Hg, making it harder to obtain arterial access. Of note, one patient in the US-guided group and one of the palpation-group patients who required US rescue were on norepinephrine. Although they were only moderately hypotensive at the time of placement, arterial constriction at the wrist made placement very difficult, and the operators actually visualized catheter placement within the artery without a flash of blood being obtained.

LIMITATIONS

Although it was unavoidable in this case, the possibility that group assignment may have influenced the speed of the operator must be acknowledged as a limitation of this study design. All four researchers had experience with emergency US. Specifically, all four had used US as an adjunct for both central and peripheral vascular access. The inclusion of less-experienced operators in the data collection process might have produced different results. In addition, all four researchers had ample experience with blind arterial cannulation. We believed that using researchers who were novices to either US guidance for vascular access or to blind arterial cannulation would introduce considerable and uncontrolled bias. It is possible that the differences between the palpation-placement group and US-guided group would be even further exaggerated in hypotensive patients. However, our study was not powered to make that distinction. It is important to note that three of the four data collectors are authors of this article. This introduces the possibility of bias between the US-guided and palpation-placement groups, because this study could not be effectively blinded.

CONCLUSIONS

In this study, US guidance for arterial cannulation was successful more frequently and reduced the time needed to establish the arterial line, as compared with the palpation-placement method.

Dr. Srikar Adhikari helped to contribute to data collection.

References


REFLECTIONS

Storms

There must have been a storm last night. Not the raining type, but the kind that fills the trauma bays, washes out through the halls, and overflows into the waiting room. Were paychecks mailed today? Maybe a fresh drug shipment on the streets? Or perhaps it was that notorious butterfly wing that somehow sets the whole chaos in motion. Whatever it was, we were still picking up the pieces as my night shift ended. The board told the anonymous stories of that evening’s matches: auto vs. peds, motorcycle vs. wall, head vs. sidewalk—like a poster for some gaudy sideshow at a traveling circus.

As I finished my stack of dictations, I looked down the hall lined both sides with gurneys. The night’s mayhem had mostly settled, and the complexity of those 12 lives seemed for a moment eclipsed by their common circumstance: caught in the storm, stolen from their plans, and left here to wait. I thought for a moment about the tens of thousands who would pass through that hall this year alone. Just the thought was exhausting.

On the way out, I passed the waiting room. Full, as always, with those sick enough to wait, but well enough to wait still. How many of these same people would be here tomorrow? I could not help looking at the faces. A mix of hope—am I next?—and resignation. In my entire life, have I ever sat and waited for ten hours? I wondered how many patients I managed to see that night. My aching feet knew the numbers, but what did that mean here?

Outside I found a cold but unexpectedly bright autumn morning. The asphalt was still piled with leaves. It was that way yesterday! As I brusquely kicked the wet leaves from my shoes, I mumbled sarcastically about the groundskeepers—strong work, guys. Reaching down to free myself from the last stubborn, broken leaf clinging to my pants leg, I paused and glanced back at the waiting room. Holding that leaf and looking at the thousands strewn about, I thought about the never-ending hall and finding my way back to that one patient in spite of the storm. But that morning, it was hard to see the difference between that leaf and all the rest.

Catching myself kneeling over a wet leaf in the middle of the sidewalk, I stood and tried to look professional as I headed toward the parking lot where my wife and kids would be waiting. My daughter, just three this autumn, was bundled up for school and playing on the sidewalk. She came running, her eyes sparkling with excitement. I could see she had something to show me as she reached up her hand. “Daddy, the wind gave me a leaf!”

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