Prospective Comparison of Ultrasound-Guided Versus Palpation Techniques for Arterial Line Placement by Residents in a Teaching Institution

Yar Luan Yeap, MD
John W. Wolfe, MD
Jennifer Stewart, DO
Kevin M. Backfish, MD

ABSTRACT

Background Arterial line insertion is traditionally done by blind palpation. Residents may need multiple attempts for successful insertion, leading to longer procedure times and many failed attempts.

Objective We hypothesized that ultrasound guidance (USG) would be faster and more successful than traditional blind palpation (TBP) for radial artery line placement by residents.

Methods Patients undergoing elective surgery requiring a radial arterial line were randomized to either the USG or TBP groups. Exclusion criteria included a need for arterial line placement in an awake patient, emergent surgery, or American Society of Anesthesiologists (ASA) physical status class VI. After the induction of anesthesia, a postgraduate year 3 (PGY-3) or PGY-4 anesthesia resident placed an arterial line by either USG or TBP.

Results A total of 412 patients and 85 of 106 residents (80%) in the training program were included. The 2 groups were similar with respect to sex, weight, height, ASA class, baseline systolic blood pressure, and baseline heart rate. USG was faster than TBP (mean times 171.1 $\pm$ 16.7 seconds versus 243.6 $\pm$ 23.5 seconds, $P = .012$), required fewer attempts (mean 1.78 $\pm$ 0.11 versus 2.48 $\pm$ 0.15, $P = .035$), and had an improved success rate (96% versus 90%, $P = .012$).

Conclusions We found that residents using USG in an academic institution resulted in significantly faster placement of the arterial lines, fewer attempts, and fewer catheters used.

Introduction

Approximately 8 million arterial catheters are placed each year in the United States,[1] and many of these are performed at teaching institutions. The traditional approach to place an arterial catheter is by blind palpation (TBP), but ultrasound guidance (USG) may also be used to locate the artery. Anesthesia residents (as well as those in other specialties, such as emergency medicine and critical care) are expected to be proficient in arterial line placement by the end of their training. Even though most residents gain a lot of experience placing arterial lines, TBP continues to challenge even the most experienced residents. Palpation of the radial artery may be difficult in patients with obesity, hypotension, tachycardia, or pitting edema.[2] This may lead to repeated unsuccessful attempts, potentially causing arterial hemorrhage, hematoma, spasm, or creation of a false lumen.[3]

The vascular access capabilities of the ultrasound have been used most for central venous cannulation in the intensive care unit and operating room.[4,5] The US Centers for Disease Control and Prevention recommends USG for central venous catheter placement, as the technique leads to fewer attempts and complications than the traditional landmark technique.[6,7] Recent meta-analyses comparing TBP with USG for radial arterial cannulation all show significantly improved first-attempt success rate with USG, and other improved outcomes, including decreased failure rate, decreased number of attempts, shorter duration, and decreased complications.[8–11] To our knowledge, there have been no large randomized controlled studies to investigate USG in an anesthesiology residency program where all arterial cannulations are first performed by residents.

We hypothesized that in a teaching hospital, USG would improve residents' arterial line placement time as well as decrease the number of attempts, sites, catheters used, and operators required.

Methods

Patients

Patients were recruited between 2014 and 2016 from Indiana University Health University Hospital, a large academic medical center where residents place multiple arterial lines daily. The participants were randomized by a computer program (Research

DOI: http://dx.doi.org/10.4300/JGME-D-18-00592.1

Randomizer, www.randomizer.org) into the TBP or USG group. Patients with American Society of Anesthesiologists (ASA) physical status classes I to IV qualified for the study.[12] No eligible ASA class V patient presented for elective surgery during that time. Excluding factors included arterial catheterization in an awake patient, preexisting arterial catheterization during the same visit within 7 days, and emergency surgery.

What was known and gap
The traditional approach to place an arterial catheter is by blind palpation, but it is a difficult procedure that often leads to failed attempts.

What is new
A randomized study to compare the procedure time and outcomes of blind palpation with ultrasound guidance for placing an arterial catheter.

Limitations
Study did not control for resident skill or the role supervising staff anesthesiologists' judgment might have played in the outcomes.

Bottom line
Ultrasound guidance leads to faster and more successful arterial line placement by anesthesia residents.

Residents

All radial artery catheterizations were performed by trained postgraduate year 3 (PGY-3) or PGY-4 anesthesiology residents with similar levels of experience in both TBP and USG radial arterial catheterization. Residents are trained on these techniques during their intern year; therefore, all residents had done at least 5 TBP and 5 USG radial arterial catheterizations prior to the study. The anesthesia residency program accepts 25 to 27 trainees per year, and all residents agreed to participate; over the course of 2 years there were 106 PGY-3 and PGY-4 residents eligible for this study.

Procedures

All patients underwent induction of general anesthesia and endotracheal intubation. Radial artery cannulation was performed according to the randomized method using a radial artery catheterization kit (Arrow International Inc, Reading, PA). For all patients, the skin near the insertion site was cleaned with chlorhexidine according to standard protocol. The wrist was extended and taped to a board to maintain wrist extension.

For the USG method, a portable ultrasound device (Venue, GE Healthcare, Chicago, IL) was applied to the skin to localize the radial artery and a 20-gauge catheter was inserted distal to the transducer and directed according to the ultrasound image. Start time was defined when the ultrasound machine was placed on the wrist. Ultrasound use was dynamic during this period.

For the TBP method, the radial artery was identified by palpation, and the cannula was directed by continued or intermittent palpation of arterial pulsation. The start time was defined as the time when the operator's finger was initially placed on the patient's wrist. The end point for both methods was successful arterial cannulation. Times were recorded by the same research nurse to ensure consistency of the start and stop times for both techniques.

Other recorded factors included the success rate for the chosen method, as well as the number of catheterization attempts, sites and catheters used, and operators required to insert the arterial line. The staff anesthesiologist supervising the resident acted as the second operator when required. An attempt was defined as a new penetration of the skin with the needle, followed by an unlimited number of needle redirections under the skin. A new catheter kit was not required for each new attempt if that catheter never entered the artery and was not filled with blood. A new site was defined as moving to the other wrist or another backup artery. One anatomic site could potentially be used for all attempts. Clinical judgment by the supervising staff anesthesiologist was used to determine the time allowed for an attempt, number of attempts allowed, changes to a new site, etc. Success was defined as the ability of the resident to cannulate an artery using the method that had been randomly assigned to that patient. In cases of failure, an alternative method was used to place the arterial catheter.

This prospective, randomized study was approved by the Indiana University Hospital Institutional Review Board.

Statistical Analysis

Mean, standard error, median, and range were calculated for all continuous variables. Frequencies and percentages were calculated for all categoric variables. The primary outcome, demographic data, and the time elapsed were compared between the 2 groups using independent samples *t* tests. Number of attempts, first-time success rate, number of sites used, number of catheters used, and number of operators required to insert the arterial line were analyzed using a 1-way analysis of variance (ANOVA). A 5% significance level ($P < .05$) was used for all comparisons. Statistical analysis was performed using SPSS Statistics 23.0 (IBM Corp, Armonk, NY).

TABLE 1
Summary Statistics of Patient Demographics

Variables	Arterial Line Technique Type			*P* Value
	Total (n = 412)	Blind Palpation (n = 206)	Ultrasound Guided (n = 206)	
Sex, No. (%)				.55
Female	204 (49.5)	99 (48.1)	105 (51.0)	
Male	208 (50.5)	107 (51.9)	101 (49.0)	
Weight, kg				.97
Mean ± SE	88.0 ± 1.4	88.0 ± 2.0	87.9 ± 2.0	
Median (min–max)	83.0 (36.4–243.0)	84.0 (36.5–243.0)	82.6 (36.4–194.0)	
Height, cm				.19
Mean ± SE	168.9 ± 0.8	169.9 ± 0.8	167.8 ± 1.4	
Median (min–max)	170.2 (5.8–196.9)	170.2 (73.8–192.0)	170.0 (5.8–196.9)	
ASA class, No. (%)				.63
I	1 (0.2)	0 (0)	1 (1)	
II	19 (5)	8 (4)	11 (5)	
III	387 (94)	196 (95)	191 (93)	
IV	5 (1)	2 (1)	3 (2)	
V	0 (0)	0 (0)	0 (0)	
Baseline SBP, mm Hg				.71
Mean ± SE	134.2 ± 1.2	134.6 ± 1.7	133.7 ± 1.8	
Median (min–max)	134.0 (68–222)	135.5 (68–222)	132.5 (74–214)	
Baseline heartrate (beats/min)				.19
Mean ± SE	85.7 ± 0.8	86.7 ± 1.1	84.6 ± 1.2	
Median (min–max)	85.0 (43–178)	87.0 (45–135)	83.0 (43–178)	

Abbreviations: ASA, American Society of Anesthesiologists physical status; SBP, systolic blood pressure.

Results

A total of 421 patients and 85 of 106 residents (80%) participated in the study. Five patients (all from the TBP group) were excluded due to protocol violations. Two patients (both from the TBP group) were excluded due to incorrect data documentation. One patient (TBP group) was excluded because the arterial line placement was aborted shortly after starting the procedure.

Both groups were similar with respect to sex, weight, height, ASA class, baseline systolic blood pressure, and baseline heart rate (TABLE 1). Time required to insert the arterial line was longer for the TBP group compared with the USG group (mean 243.6 seconds versus 171.1 seconds, $P = .012$; TABLE 2). The USG method resulted in fewer attempts than the TBP method (mean 1.78 versus 2.48, $P < .001$), fewer catheters used (mean 1.39 versus 1.59, $P = .035$), and higher success rate (96% versus 90%, $P = .012$; TABLE 3). The mean number of operators was 1.09 (resident is first operator and staff anesthesiologist is second operator).

Discussion

Using USG to assist in arterial catheterization by residents led to superior outcomes in our study, as it was faster, required fewer attempts and fewer catheters, and had a better success rate. These results are consistent with those of published studies,

TABLE 2
Time for Successful Arterial Line Placement by Residents

Variable	Arterial Line Technique Type			*P* Value
	Total (n = 412)	Blind Palpation (n = 206)	Ultrasound Guided (n = 206)	
Time, s				.012
Mean ± SE	207.3 ± 14.5	243.6 ± 23.5	171.1 ± 16.7	
Median (min–max)	87.5 (9–3086)	111.0 (9–3086)	76.5 (11–1410)	

TABLE 3
Other Outcome Variable Comparisons Between 2 Groups

Variables	Arterial Line Technique Type			*P* Value
	Total (n = 412)	Blind Palpation (n = 206)	Ultrasound Guided (n = 206)	
Total number of attempts				< .001
Mean ± SE	2.13 ± 0.095	2.48 ± 0.147	1.78 ± 0.114	
Median (min–max)	1.00 (1–11)	2.00 (1–11)	1.00 (1–10)	
Total number of sites used				.10
Mean ± SE	1.13 ± 0.019	1.16 ± 0.031	1.10 ± 0.022	
Median (min–max)	1.00 (1–5)	1.00 (1–5)	1.00 (1–3)	
Total number of catheters used				.035
Mean ± SE	1.49 ± 0.047	1.59 ± 0.072	1.39 ± 0.061	
Median (min–max)	1.00 (1–7)	1.00 (1–7)	1.00 (1–6)	
Total number of operators required				.17
Mean ± SE	1.09 ± 0.014	1.11 ± 0.022	1.07 ± 0.018	
Median (min–max)	1.00 (1–2)	1.00 (1–2)	1.00 (1–2)	
Completion of A-line placement, No. (%)				.012
Not successful	29 (7)	21 (10)	8 (4)	
Successful	383 (93)	185 (90)	198 (96)	

although none of the previous trials specifically evaluated anesthesia residents.

Our results suggest that academic medical centers should consider using USG for any challenging radial arterial catheterization (eg, patients with complicating factors, such as morbid obesity, tissue edema, hypoxia, and vasoconstrictor therapy). This information is not only relevant for anesthesia training programs, but also other specialties, including emergency medicine, critical care, and surgery.

The number of failures with each technique is interesting, as 13 additional patients in the TBP group had failed procedures compared with the USG group. This supports the use of USG for arterial line placement to improve patient experience. Additionally, although the difference in catheter kits required between the groups was small, if these numbers are projected to the entire study population (412 patients), 82 fewer catheter kits would be required, with cost savings for the institution.

Limitations to this study include the lack of controlling for resident skill with each technique, which may have introduced bias if residents who have more skill with USG were assigned more patients randomized to this approach, or the reverse for TBP technique. However, residents were generally more familiar with TBP, although the study results show an advantage to USG. Because the analysis did not control for the supervising staff anesthesiologist (whose clinical judgment affected some outcomes), variability in the judgment may have biased these outcomes in unknown ways. Finally, we used the same catheter kit and ultrasound for all study procedures, but the specific catheterization kit, ultrasonography equipment, USG approach, and other variables may potentially affect outcomes at other institutions.

In light of these findings, further studies of resident training and use of USG at other sites, in other settings, and with other specialties are recommended.

Conclusion

Our study showed that USG leads to faster and more successful arterial line placement by anesthesia residents.

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All authors are with the Department of Anesthesia, Indiana University School of Medicine. **Yar Luan Yeap, MD,** is Assistant Professor of Anesthesiology; **John W. Wolfe, MD,** is Assistant Professor of Anesthesiology; **Jennifer Stewart, DO,** is Assistant Professor of Anesthesiology; and **Kevin M. Backfish, MD,** is Assistant Professor of Anesthesiology.

Funding: The authors report no external funding source for this study.

Conflict of interest: The authors declare they have no competing interests.

The authors would like to thank Janelle S. Renschler, DVM, PhD, for providing assistance with medical writing, editing, and references.

Corresponding author: Yar Luan Yeap, MD, Indiana University School of Medicine, Department of Anesthesia, FH 204, 1120 South Drive, Indianapolis, IN 46202, 317.440.2040, yyeap@iupui.edu

Received July 27, 2018; revision received November 19, 2018; accepted January 16, 2019.