Original Article

Increasing the Success Rate of First-Year Anesthesia Residents Using Ultrasound for Radial Artery Catheterization Compared to the Palpation Method in Adult Surgical Patients

Dariush Abtahi[1*], Nima Saeedi[1]

[1]Department of Anesthesiology, Imam Hossein Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran

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Abstract

Background: The palpation method is commonly used to perform radial artery catheterization, but it has a high failure rate. We conducted this study to determine the efficacy of early ultrasound training in improving the success rate of first-year anesthesia residents in radial artery catheterization with palpation technique because the use of ultrasound can increase the success rate.

Materials and Methods: In this randomized controlled trial, 320 patients underwent radial arterial catheterization in the first stage (training) and another 320 patients in the second stage (research) in two groups of residents who were trained by palpation or ultrasound guidance. The primary endpoint was the first-try success rate, and the secondary endpoints were the final success rate, time to achieve first and final success, hematoma incidence, and the number of attempts.

Results: The success rate of the first try in the ultrasound group was significantly higher (71.3%) compared to the palpation group (52.5%, P<0.001). The number of attempts, time to success on the first try, and overall succession were all higher in the palpation group (P<0.05). There were no significant differences in overall success rate or hematoma formation (P>0.05).

Conclusion: Ultrasound training for first-year anesthesia residents improves the success rate of arterial catheterization via palpation.

Keywords: Peripheral arterial catheterization, Radial artery, Palpation, Ultrasonography

***Corresponding Author:** Dariush Abtahi, MD, Assistant Professor of Anesthesiology, Clinical Research and Development Unit, Imam Hossein Hospital, Anesthesiology Department, Shahid Beheshti University of Medical Sciences, Tehran, Iran. Tele/Fax: (+98) 21 77547840/ (+98) 21 77547840. Email: drdariushabtahi@yahoo.com

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Introduction

Radial artery catheterization dates back to 1949 and is still used in operating rooms, intensive care units, and emergency rooms. This method allows for continuous arterial blood pressure measurement and arterial sampling[1]. Because of its superficiality and simplicity of access, the radial artery is used more than other arteries, and because of the dual blood supply in the hand, there is less risk of problems while catheterizing this artery[2,3]. The most prevalent problems linked with this technique were temporary artery blockage and hematoma development. Serious problems, such as prolonged ischemia, pseudoaneurysm development, and infection, occur in less than 1% of patients[4]. This technique is more difficult to conduct in persons who have obesity, low blood pressure, or peripheral edema, which may necessitate several or unsuccessful efforts

by the clinician[2]. As a result, success on the first try is critical to save time and prevent subsequent difficulties. However, depending on the performer, the success percentage of this strategy on the first attempt is rather low, ranging between 13.9 percent and 50 percent[2].

Ultrasound-guided catheterization has been pushed in recent years as a way to minimize failure rates and consequences[5]. Previous research has used varied implementation methods in terms of patient groups (e.g., children, adults), clinician groups (e.g., residents, anesthesiologists), and implementation techniques (e.g., out-of-plane, in-plane), and the findings are expected to differ. Some research found that ultrasound is superior to tactile methods method[2,3,6–11] whereas others did not[12–14]. Furthermore, various ultrasound methods have shown disparate findings[3,5,15–17]. Ultrasound training is suggested for residents of numerous specialties due to a large number of confirmatory investigations[8,10,18–21]. The cost of ultrasound equipment, restricted access to it, and limited access to training and training fees are all disadvantages of utilizing ultrasonography[9].

To the best of our knowledge, no research on the influence of first-year resident training on radial artery catheterization quality has been undertaken in Iran. We looked at how ultrasonography training affected the success rate, time of catheterization, and potential problems in first-year anesthesia residents.

Methods

This study was authorized by the Ethics Committee of Shahid Beheshti University of Medical Sciences in Tehran, Iran (IR.SBMU.REC.1397.010) and the Iranian Registry of Clinical Trials (IRCT20120910010800N5). The sample size was calculated using PASS software (Ver. 15, NCSS Statistical Software, USA) and data from a recent randomized trial[22] that evaluated the ultrasound guidance and palpation methods for radial artery catheterization (the first try succession rate was 64.8 and 43.9 percent, respectively). Given the inexperience of anesthesia residents, we estimated this incidence to be about 35%. The total number of specimens was determined to be 261, assuming that a 20% improvement in outcomes using ultrasound guiding resulted in significant changes. With a 20% decline in cases expected, the overall number was anticipated to reach 313.2. Finally, in the first stage, 320 patients were evaluated, and the same was studied in the second stage (Figure 1, 2). Randomization was done using PASS software by a methodologist consultant who did not intervene in the research. Patients are selected for each resident by the available sampling method and assigned to one of the two methods of palpation and radial artery catheterization based on the randomization sequence prepared using PASS software using the randomization method with permutation blocks with a block size of 4 with the allocation (2x2). In randomization, each resident is considered a stratum. allocation of patients with this method will be done by an anesthesiologist who will not be involved in the next stages of the research and before the patient enters the operating room by opening the non-transparent sealed envelope containing the name of the group. Both patients and observers were blinded to the treatment group. The first phase was carried out from April 21, 2021, to May 22, and the second phase from July 1, 2021, to August 1, 2021, all in a university-affiliated teaching hospital operating room.

The first phase (training): The study included 20 first-year anesthesia residents who were inexperienced with ultrasonography or artery catheterization. All residents were given a training program on anatomy, catheterization site preparation, use of the ultrasound equipment, and basic understanding of palpation and ultrasound for radial artery catheterization using video files[23,24] and oral lectures. This instruction was carried out multiple times. Following that, the residents were divided into two groups for catheterization by palpation (P) and ultrasonography (US).

Three hundred twenty patients over the age of 18 with an American Society of Anesthesiologists (ASA) physical status class one or two who needed arterial blood pressure measurement for elective surgery in the operating room of a teaching hospital were studied after obtaining written informed consent from all study participants. If a patient had a history of peripheral artery disease, skin inflammation, recent surgery around the puncture site, an abnormal Allen test[25], or a history of radial artery catheterization within the preceding month, they were removed from the research. Continuous electrocardiography, pulse oximetry, noninvasive blood pressure, and capnography were

used to monitor the patient before general anesthesia. The patient was subsequently subjected to a modified Allen's test, in which the elbow was flexed first while the fist was clinched to drain blood from the hand. The examiner's fingers were then used to squeeze the radial and ulnar arteries at the same time. The fist was then opened, revealing a white palm. The pressure was then released from the ulnar artery while remaining on the radial artery, and the palm color should return to normal within 10 seconds. If color normalization has not occurred by this point, the test is deemed abnormal, and the subject is withdrawn from the research. If the modified Allen's test was normal, the wrist (ideally the non-dominant one) would be bent backward and a pillow would be put beneath it. The hand was taped at a 45-degree angle where the greatest pulse was detected.

After general anesthesia and catheter site preparation, arterial catheterization was performed in Group P using a 20G size Lifemed intravenous catheter (iLife Medical Devices Pvt Ltd, Sonipat, India) at an angle of roughly 30 degrees to the radial artery using the catheter-over-needle technique. When blood appeared in the hub, the entry angle was adjusted to 15 degrees to minimize arterial injury, and the catheter progressed into the artery while the internal stylus was held in place. These steps can be seen in the New England Journal of Medicine video[26]. If arterial blood flow had ceased after completely removing the inner stylus, the catheter was withdrawn slightly and the inner stylus was reinserted. After reestablishing pulsatile blood flow, the catheter was gently advanced, and the procedure described above was repeated. In the US group, ultrasound equipment (S-nerve; FUJIFILM SonoSite Inc., Tokyo, Japan) was utilized to do ultrasound by a 50x HFL probe (6-15 MHz/linear array/6 cm scan dept FUJIFILM SonoSite Inc., Tokyo, Japan) via long-axis in-plane technique (Figure 3, 4). The ultrasonic probe was inserted on the insertion site under sterile circumstances in this group. The artery's non-compressible pulse aided in identifying it. Color Doppler was utilized to help locate arteries as necessary. The catheter progression was carried out in the same manner as in group P. When blood flowed in the hub, the probe was withdrawn, and the subsequent stages were carried out in the same manner as in group P.

Catheter placement in a radial artery in less than 5 minutes without changing technique or operator was considered successful. The period of initial success was defined as the time between the first time the catheter was inserted into the skin and its perfect placement in the radial artery. If there was no success in less than 5 minutes, catheterization was done on the other hand or utilizing a catheter-over-wire approach with a different type of catheter (arrow arterial catheterization set, SAC-00822: 20 ga 8 cm, Teleflex, Ireland). If the operator failed three times in five minutes, the anesthesiologist in charge would make the proper choice on his or her own. Any entry through the skin was considered an attempt, although redirections via the skin were not. Throughout the process, the anesthesiologist attended with the resident.

Following successful catheterization, the catheter was connected to a pressure transfer kit loaded with heparinized saline and subsequently to the monitoring system. Observing the arterial wave in the monitor proved the catheterization's success. A sterile coating was applied to the catheters (BPI Tebbi Shafa Gauze Swabs, Qazvin, Iran). After surgery, the catheter was withdrawn, and the catheter entrance site was coated with a sterile dressing and wrapped in 3 to 5 cycles of compression bandage (Syna Moderate Compression Bandage, Tehran, Iran) for homeostasis.

Each resident in the P group conducted radial artery catheterization by palpation in 16 patients, whereas each resident in the US group employed ultrasound-guided catheterization in 16 patients. The training program was repeated with lectures and video files for the residents at the end of this step and before starting the second.

Second Phase (study): During this phase, each resident catheterized 16 additional patients utilizing the identical palpation methods and procedures detailed in the training phase (a total of 320 samples). Finally, the results of the second stage were assessed. The success rate of the first attempt was the starting endpoint. The overall success rate, time to eventual success, number of tries, number of catheters utilized, and incidence of hematoma were all secondary objectives.

The Shapiro-Wilk test was used to test data normality, and non-parametric tests were utilized owing to data distribution abnormalities. The chi-square test was used to analyze the influence of the catheterization technique

on initial and ultimate success, as well as the times measured and the number of tries. Spearman's correlation was used to examine the factors influencing them. We utilized multivariate logistic regression to identify the components related to the initial try and the final succession. P-value < 0.05 was considered statistically significant. SPSS software was used for statistical analysis (version 17; SPSS, Chicago, IL, USA).

Results

Patients over the age of 18, with ASA I and II, who had surgery at a teaching hospital with intra-arterial blood pressure monitoring were split into P and US groups. Seven patients were dropped from the second phase owing to discontent, twelve due to opposition to the planned group, and one due to a lack of necessity for radial artery catheterization. The remaining 320 patients were randomly picked from among 20 residents for radial artery catheterization, with half receiving ultrasonography.

Table 2 presented the study's findings. One hundred fourteen patients (71.3%) in the US group displayed effective catheterization on the first try, but only 84 (52.5%) were in group P, and the difference was significant (P<0.001). Although the end success rate in the US group was greater than in the P group, the difference was not statistically significant (81.3% vs. 80.0%, respectively). Age, gender, BMI, ASA, smoking, and diabetes or hypertension were found to not affect first-attempt and overall success rates (P>0.05) using multivariate logistic regression.

Catheterization required less time on the first try in the US group (P=0.007). Furthermore, the median (interquartile range) time for the first catheterization attempt in the US group was 112 seconds (IQR=104) and 123 seconds (IQR=130) in the P group. The ultimate catheterization time was substantially shorter in the US group than in the P group (P<0.001). In the US group, the median (interquartile range) time was (132 seconds, IQR=160) less than in the P group (149.50 seconds, IQR=149). There was no link between catheterization success time at first try and time to final success using Spearman's correlation test and age, gender, body mass index (BMI), ASA, smoking, diabetes, or hypertension (P>0.05).

Catheterization attempts were observed to be substantially more common in group P (P=0.007). Using Spearman's correlation test, it was shown that a higher number of tries was significantly linked with hematoma occurrence (P<0.001) but not with age, gender, weight, ASA, smoking, diabetes, or hypertension (P>0.05). Furthermore, despite a substantial difference in the number of successful attempts between the two groups, the difference in the number of catheters utilized was not significant (P=0.161).

Thirteen patients (8.1%) in group P and 12 (7.5%) in

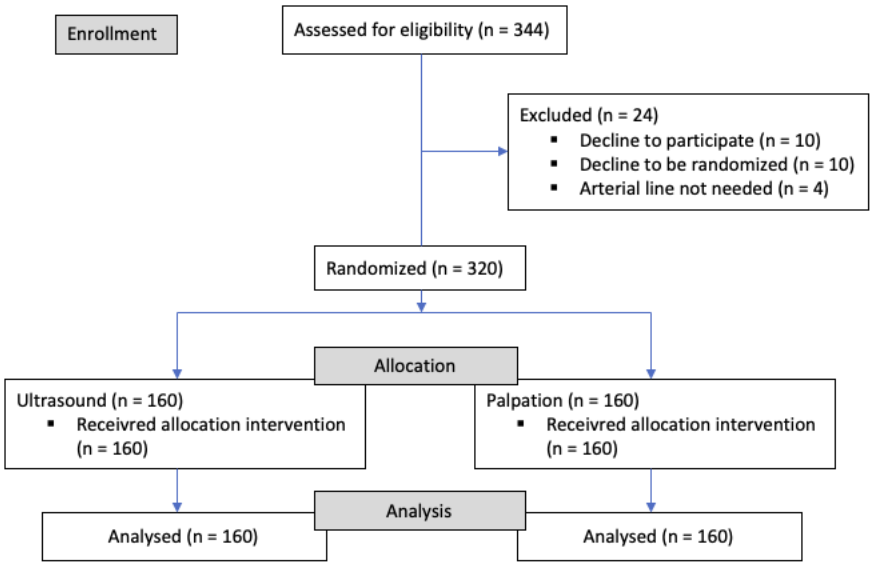

Figure 1. Patient enrollment (phase 1).

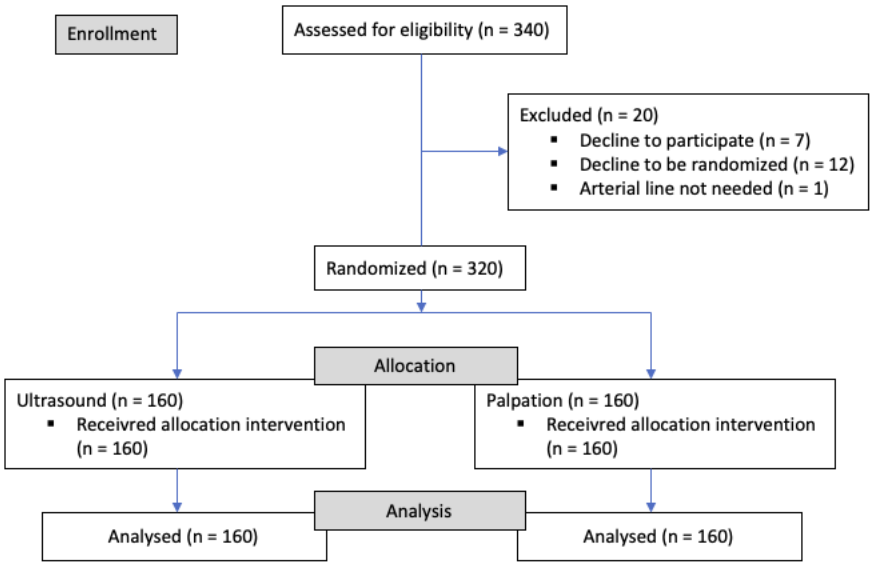

Figure 2. Patient enrollment (phase 2).

Figure 3. Longitudinal view of radial artery.

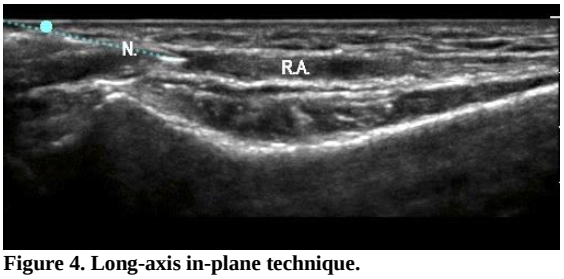

Figure 4. Long-axis in-plane technique.

group US required an alternate way using the catheter-over-wire technique, and the difference was not statistically significant (P=0.835). In all instances when an alternative procedure was required, the success rate was 100 percent. The difference in the necessity to use the other hand or change the performer (who was the anesthesiologist in charge of the patient) between the two groups was not statistically significant (P>0.05).

The development of hematomas was more prevalent in the US group than in the P group, although the difference was not statistically significant (P=0.325). There was no link between the rate of hematoma and gender, BMI, right or left-hand usage, smoking, diabetes, or hypertension (P>0.05).

Discussion

Our study found that ultrasound-trained anesthesia residents were more effective on the first try at radial artery catheterization than those who learned the palpation approach and did so in less time. In this group of residents, the overall number of catheterization attempts was similarly lower. Although ultrasound training did not affect the overall success rate, ultrasound-trained residents completed the study in less time. The use of ultrasonography did not lower the frequency of hematoma at the location of the radial artery puncture in our investigation. We also do not know about the late occurrence of pseudoaneurysms.

In a 2018 meta-analysis published by Bhattacharjee et al., data from 1895 patients in 10 trials were reviewed. They found, similar to our study, utilizing ultrasound can enhance the rate of first-attempt succession but has no effect on the overall success rate. In contrast to our findings, the use of ultrasonography did not affect the

Table 1: Patient Characteristics; SD: standard deviation, BMI: body mass index, DM1: diabetes mellitus type 1, DM2: diabetes mellitus type 2, HTN: hypertension, ASA: American Society of Anesthesiology class.

Variables		Technique		Overall	P-value
		Ultrasound	Palpation		
Gender	**Male/Female, n (%)**	72 (45.0%)/88 (55.0%)	66 (41.3%)/94 (58.8%)	138 (43.1%)/182 (56.9%)	0.573
Age	**Mean (SD)**	45.16 (15.17)	48.21 (16.62)	46.68 (15.96)	0.127
	18-30, n (%)	20 (12.5%)	18 (11.3%)	38 (11.9%)	
	31-50, n (%)	87 (54.4%)	71 (44.4%)	158 (49.4%)	
	51-70, n (%)	41 (25.6%)	48 (30.0%)	89 (27.8%)	
	>71, n (%)	12 (7.5%)	23 (14.4%)	35 (10.9%)	
BMI	**Mean (SD)**	25.67 (3.78)	26.00 (4.07)	25.83 (3.89)	0.863
	Underweight, n (%)	5 (3.1%)	4 (2.5%)	9 (2.8%)	
	Normal Weight, n (%)	54 (34.0%)	58 (36.7%)	112 (35.3%)	
	Overweight, n (%)	81 (50.9%)	74 (46.8%)	155 (48.9%)	
	Obese, n (%)	19 (11.9%)	22 (13.9%)	41 (12.9%)	
DM1, n (%)		10 (6.3%)	7 (4.4%)	17 (5.3%)	0.619
DM2, n (%)		21 (13.1%)	20 (12.5%)	41 (12.8%)	1.000
HTN, n (%)		23 (14.4%)	15 (9.4%)	38 (11.9%)	0.226
Smoking, n (%)		47 (29.4%)	47 (35.6%)	104 (32.5%)	0.283
ASA	**I/II, n (%)**	67 (41.9%)/93 (58.1%)	77 (48.1%)/83 (51.9%)	144 (45.0%)/ 176 (55.0%)	0.312
Side of Hand	**Right/Left, n (%)**	51 (31.9%)/109(68.1%)	48 (30.0%)/112 (79.0%)	99 (30.9%)/221 (69.1%)	0.809

timing or number of catheterization attempts (12). Another review of pediatric trials by Zhang et al. found that using ultrasonography might improve catheterization success rates and reduce the frequency of hematoma (11). In another study, Ganesh et al. found that employing ultrasonography had no statistically significant effect on successful catheterization time, the total number of tries, the rate of successful catheterization on the first try, or the number of catheters used in pediatric patients Kim et al. found that ultrasound-guided catheterization was related with greater success and fewer problems in individuals over the age of 65 (10). Another research in children weighing less than 20 kg found that this approach was more successful and faster than palpation on the first and third tries, with a lower rate of hematoma development than the palpation group (7). Another study conducted by experienced cardiac anesthesiologists discovered that using ultrasonography did not influence placement duration, the number of redirections or tries, the success rate on the first try, total failure, or hematoma development when compared to palpation (14).

The majority of the trials described above were done on pediatric patients and in mixed groups of residents and specialists with varying degrees of experience. Furthermore, few studies have concentrated on teaching residents how to use ultrasonography to improve their performance. Oh et al. conducted a trial in which anesthesia residents who were unfamiliar with ultrasound-guided radial artery catheterization were given simulation-based training on a vascular phantom. In actual patients, they discovered an enhanced success rate for the first try at ultrasound-guided radial artery catheterization (21). Yeap et al. showed that using ultrasound instead of palpation results in faster success,

Table 2: Study Results; CI: confidence interval, IQR: interquartile range, SD: standard deviation.

Variables		Technique				Relative Risk (95% CI)
		Ultrasound	Palpitation	Overall	P-value	
First Pass Success, n (%)		114 (71.3%)	84 (52.5%)	198 (61.9%)	<0.001	2.2 (1.4-3.6)
Overall Success, n (%)		130 (81.3%)	128 (80.0%)	258 (80.6%)	0.888	1.1 (0.6-1.9)
Number of attempts	**Mean (SD)**	1.34 (0.62)	1.59 (0.75)	1.47 (0.69)	0.007	
	1, n (%)	117 (73.1%)	91 (56.9%)	208 (65.0%)		
	2, n (%)	31 (19.4%)	44 (27.5%)	75 (23.4%)		
	3, n (%)	12 (7.5%)	25 (15.6%)	37 (11.6%)		
Time for First Success (seconds), Median cannulation time (IQR)		112.00 (104)	123.00 (130)	118.00 (151)	0.007	
Total Time (seconds), Median cannulation time (IQR)		132.00 (160)	149.50 (149)	135 (170)	<0.001	
Number of catheters used, n (%)	1	115 (71.9%)	101 (63.1%)	216 (67.5%)	0.161	
	2	39 (24.4%)	47 (29.4%)	86 (26.9%)		
	3	6 (3.8%)	12 (7.5%)	18 (5.6%)		
Change to another performer, n (%)		17 (10.6%)	16 (10.0%)	33 (10.3)	0.854	1.1 (0.52-2.20)
Change to another technique, n (%)		12 (7.5%)	13 (8.1%)	25 (7.8%)	0.835	0.92 (0.41-2.08)
Change to another site (change in hand), n (%)		27 (16.9%)	37 (23.1%)	64 (20%)	0.162	0.68 (0.39-1.17)
Complications	**Hematoma**	35 (21.9%)	28 (17.5%)	63 (19.7%)	0.325	1.32 (0.76-2.30)
	Arterial Spasm	25 (15.6%)	38 (23.8%)	63 (19.7%)	0.068	0.60 (0.34-1.04)

fewer tries, and fewer catheters required (18). There was no significant variation in the number of catheters utilized in our investigation. Catheterization was conducted on both hands of patients in the study by Gopalasingam et al., and they compared the palpation technique on one hand and ultrasonography on the other. Four residents took part in this study. The ultrasound group had a higher success rate on the first try and needed fewer catheters. However, ultrasonography cannot shorten the time required for catheterization (20).

Finally, the current study looked at the acute outcomes. Case reports of pseudoaneurysms after radial artery catheterization are concerning[27–29]. There are also worries concerning bacterial colonization and its consequences. Large studies comparing palpation to ultrasound-guided approaches can pave the path for further research into these delayed consequences.

Our research has several limitations. First and foremost, all catheterized patients were hemodynamically stable, with a detectable pulse. Furthermore, the operators were not under time pressure. The advantages of

ultrasonography could be more obvious in unstable patients, who frequently have low blood pressure and for whom time is of importance. The second constraint was that residents' general experience levels might differ, either within the same group or when compared to another group.

Another constraint was determining the time interval for success on the first try. In our investigation, "time zero" was when the catheter penetrated the skin. This definition differed from those used in previous research. In larger research, the "zero time" might be set at the point at which the ultrasound equipment is turned on.

Conclusion

We found the apparent necessity for regular updating in education, the innovation of medical programs, and the reliability of teaching materials in the age of virtual and online learning platforms. This study found that using ultrasonography to educate residents can increase their performance in radial artery catheterization, even if they use the palpation technique after learning by ultrasound method. The findings of this study further suggest that if ultrasound equipment is available, radial artery catheterization should be performed using the ultrasonography approach. Also, if feasible, use this gadget to instruct residents in regions with limited resources. Future research should also look at the prevalence of infection and pseudoaneurysm during radial artery catheterization using ultrasound guidance.

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Conflict of Interest

The authors declare that they have no known financial or interpersonal conflicts that would have seemed to have an impact on the research presented in this study.

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