Comparison of Effects of Guidewire-Assisted and Direct Arterial Puncture Techniques on Success Rate of Radial Artery Cannulation by Inexperienced Trainees

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Abstract

Background: The radial artery is superficially palpable and easily accessible, making it the preferred site for arterial cannulation. Various placement techniques are available for radial artery catheter insertion. However, catheter insertion is sometimes difficult and requires multiple attempts, especially by inexperienced trainees, leading to technical failure and insertion-related complications. Guidewire-assisted cannulation is a simple and effective technique, but this maneuver requires practice. The main objective of this study was to compare the effects of a direct arterial puncture and a guidewire-assisted cannulation technique on the success rate of radial artery cannulation by inexperienced trainees.

Methods: This study was a prospective, single-center, single-arm clinical trial with a historical control. Sixty patients with an American Society of Anesthesiologists physical status of I to III underwent elective surgery requiring radial artery cannulation. In the guidewire-assisted cannulation group (GW group), thirty radial artery cannulations were performed by inexperienced surgical residents using a guidewire-assisted cannulation technique. In the direct arterial puncture group (DP group), 30 patients underwent radial artery cannulation with a direct arterial puncture technique by inexperienced anesthesiology residents. The primary outcome was the success rate.

Results: There were no differences in the baseline blood pressure or comorbidities between the two groups. Overall, the success rate of radial artery cannulation in the GW and DP groups were 90% and 50%, respectively ($P = 0.001$). The success rate of first-attempt cannulation in the GW and DP group were 66.7% and 26.7%, respectively ($P = 0.002$). The total procedural performance time was significantly shorter in the GW than DP group.

Conclusion: The guidewire-assisted cannulation technique achieved a higher success rate than the direct arterial puncture technique when performed by inexperienced trainees.

Trial registration

The trial was registered on Thai Clinical Trials Registry (TCTR20200601004). Date of registration was January 19, 2020. (Retrospectively registered) http://www.thaiclinicaltrials.org/page_user/#

Background

Invasive blood pressure monitoring is commonly used in patients requiring continuous blood pressure measurement or frequent blood sampling.[1] The radial artery is the most commonly used artery for this purpose because of its superficial location and fewer complications compared with other sites.[2] Catheter placement can be performed using various techniques, including direct arterial puncture or palpation as well as guidewire-assisted or ultrasound-guided arterial line placement.[3] In training programs, radial artery cannulation is a compulsory procedure for anesthesiology residents. Inevitably, the risks and practice requirements of various procedures are topics of concern in any academic training center.

We mainly use a direct arterial puncture technique for radial artery catheter insertion at our institute. However, insertion of the radial artery catheter is sometimes difficult and requires multiple attempts, especially for inexperienced trainees; this may lead to insertion failure and insertion-related complications. Unsurprisingly, more experienced trainees have higher cannulation success rates. However, the development of training programs for practicing radial artery cannulation, such as pre-procedural simulator training or video demonstrations, can significantly improve the success rate for inexperienced trainees.[4] The most fundamental technique for radial artery cannulation is direct arterial puncture, which is performed without any assisting devices and has a learning curve. Therefore, its failure rate remains high among inexperienced practitioners and even some skilled anesthesiologists.[4, 5] The use of a guidewire or the Seldinger technique to aid radial artery cannulation is a reliable method that can achieve a high success rate.[6, 7] However, training and practice are required for practitioners who are unfamiliar with the technique or who have less experience.[8]

The main objective of this study was to compare the effects of direct arterial puncture, which is our standard technique, and a guidewire-assisted cannulation technique on the success rate of radial artery cannulation by inexperienced trainees. We hypothesised that guidewire-assisted cannulation can improve the success rate of cannulation.

Methods

This study was a prospective, single-center, single-arm clinical trial with a historical control. This study was approved by institutional ethics committee in Mahidol University (046125) and was registered on Thai Clinical Trials Registry (TCTR20200601004). All patients signed a written consent form before their participation in the study that was conducted from February 2019 to September 2019 at Ramathibodi Hospital, Mahidol University. The reporting in this manuscript followed the recommendations in the STROBE guideline.

All patients underwent elective hepatobiliary and pancreatic surgery under general anaesthesia, had an American Society of Anesthesiologists (ASA) physical status of I to III, were older than 18 years, and required radial artery cannulation for intraoperative monitoring. We excluded patients who required insertion of an arterial line before induction of anaesthesia, had previously undergone radial artery cannulation during the same hospital admission, had unstable vital signs, or had peripheral vascular disease. The patients were assigned into two groups; direct arterial puncture group (DP group) and guidewire-assisted cannulation group (GW group). The study was separated to two periods. The DP group was conducted when our new first-year anesthesiology residency trainees started working at the operating room after orientation program. The GW group was conducted in surgical residency trainees who rotated into division of hepatobiliary and pancreatic surgery.

In the direct arterial puncture group, the cannulation procedures were performed by first-year anesthesiology residents who had performed either zero or one radial artery cannulation. They had attended simulator training of radial artery cannulation by direct arterial puncture on a manikin-based

training and watched a video demonstrating this cannulation technique on the orientation day of our training program. In the guidewire-assisted cannulation group, radial artery cannulation was performed by inexperienced surgical residents who had only performed arterial blood gas sampling and had never performed radial artery cannulation. The study assigned only one anesthesiologist who did not involve with the patient care processes to show the video demonstrating steps of guidewire-assisted cannulation technique to surgical residents on the morning of procedure. After watching video that was approximately seven minutes in length, the surgical residents were able to ask any question before the procedure. The nurse anesthetists prepared radial artery cannulation equipment for our trainees.

Both techniques started with the patient's arm secured on an arm board, the wrist extended, and the fingers fixed. In the DP group, after cleaning the cannulation site with antiseptic solution, the direct arterial puncture began with manual palpation to identify the site of maximal pulsation. After the point of puncture had been identified, a 20-gauge fluorinated ethylene propylene polymer catheter (Jelco; Smiths Medical, Minneapolis, MN, USA) was used to puncture the skin at an angle of 30° to 45°. After arterial blood was seen in the hub of the catheter, the catheter was dropped to 5° to 10° and slightly advanced to ensure cannulation of the artery. Finally, the needle was held in place while the catheter was advanced into the radial artery. In the GW group, after arterial blood was seen in the hub of catheter, the arterial catheter was advanced through the posterior wall of the radial artery. The needle was removed and the catheter withdrawn until arterial blood pulsation was seen. Half of the guidewire (0.018" × 9¾") (Arrow; Teleflex, Wayne, PA, USA) was inserted, and the arterial cannula was then advanced into the radial artery.

Intraoperatively, all patients were maintained under general anaesthesia with an endotracheal tube. After induction of anaesthesia, radial artery cannulation was performed. All residents performed their radial artery cannulation technique without any suggestions from the attending anesthesiologists. When the residents had completed their procedure, the catheter was connected to the pressure transducer to obtain the arterial waveform.

Successful cannulation of the radial artery was defined as the appearance of an arterial waveform on the monitor after connection to the transducer. The insertion time was measured from the first needle puncture of the patient's skin to placement of the catheter into the radial artery. The number of attempts was counted as the number of needle advances through a skin puncture until the patient's blood was seen in the hub. Failure of cannulation was defined as no achievement of radial artery cannulation within two attempts or a procedural time of more than 15 minutes. In cases of failure, the arterial cannulation was performed by the attending anesthesiologist. The number of attempts and the cannulation time were recorded by nurse anesthetists who were not involved in this study. The record of procedural time was stopped when the arterial waveform was seen on the monitor or failure of cannulation. Other collected data were the patients' characteristics, ASA physical status, underlying diseases, vital signs before cannulation, and local haematoma formation after cannulation.

The sample size was calculated by the success rate of the direct puncture and guidewire-assisted techniques in a previous study[9] with a type I error of 0.05 and power of 0.8. The result indicated that 29

patients were required in each group.

Statistical analysis was performed using SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Continuous data are presented as mean $\pm$ standard deviation or median (interquartile range). Categorical data are presented as number (percentage). The chi-square test or Fisher's exact test was performed to compare categorical variables, and Student's t-test or the Mann–Whitney U test was performed to compare continuous variables in each group. Kaplan–Meier curves of the cumulative success of cannulation and the procedural performance time were plotted. The log-rank test was performed for statistical comparison of the two groups. A P-value of < 0.05 was considered statistically significant.

Results

The DP group comprised 15 first-year anesthesiology residency trainees, and the GW group comprised 30 surgical residency trainees.

A total of 60 patients participated in this study (30 in the GW group and 30 in the DP group). Table 1 shows the patients' demographic data in the two groups. There were no significant differences in age, body mass index, or comorbidities. Immediately before catheterisation, there were no significant differences in the baseline haemodynamic parameters between the two groups.

Table 1
Patient characteristics

	Guidewire-assisted group (n = 30)	Direct arterial puncture group (n = 30)	P value
Age, years	57.3 ± 14.2	58.7 ± 13.2	0.693
BMI, kg/m ²	22.4 ± 3.2	23.3 ± 4.4	0.401
Female sex	11 (36.7)	17 (56.7)	0.121
ASA physical status			0.093
1	3 (10.0)	3 (10.0)	
2	18 (60.0)	10 (33.3)	
3	9 (30.0)	17 (56.7)	
Comorbidities			
Diabetes mellitus	7 (23.3)	6 (20.0)	0.754
Hypertension	16 (53.3)	16 (53.3)	1.000
Coronary artery disease	1 (3.3)	2 (6.7)	0.557
End-stage renal disease	0 (0.0)	2 (6.7)	0.150
Before arterial catheterisation			
Systolic blood pressure, mmHg	116.7 ± 18.1	123.3 ± 24.5	0.262
Diastolic blood pressure, mmHg	66.8 ± 10.6	70.9 ± 10.9	0.148
Pulse rate, beats/min	74.9 ± 16.7	79.4 ± 13.0	0.243
Data are presented as mean ± standard deviation or n (%). BMI, body mass index; ASA, American Society of Anesthesiologists			

The overall success rate of radial artery cannulation was 27 of 30 (90.0%) patients in the GW group and 15 of 30 (50.0%) patients in the DP group ($P=0.001$). The first-attempt cannulation success rate was significantly higher in the GW than DP group (Table 2).

Table 2
Success rate and cannulation time

	Guidewire-assisted group (n = 30)	Direct arterial puncture group (n = 30)	P value
Overall success rate	27 (90.0)	15 (50.0)	0.001
Number of attempts	20 (66.7)	8 (26.7)	0.002
First-attempt success rate			
Second-attempt success rate	7 (23.3)	7 (23.3)	
Time to successful cannulation	2.36 ± 1.36	2.46 ± 1.44	0.892
Procedural performance time, min	2.24 (1.39–3.28)	4.47 (2.06–8.05)	0.033
Data are presented as n (%), mean ± standard deviation, or median (interquartile range).			

The Kaplan–Meier curve of successful insertion of the arterial line by study group is shown in Fig. 1. The log-rank test showed a statistically significant difference between the two groups ($P = 0.002$). The mean successful cannulation time was not significantly different between the two groups. However, the total procedural performance time was significantly shorter in the GW than DP group. Most of the successful cannulation times in both groups were less than 5 minutes. Among successful cannulations, 24 (88.9%) participants in the GW group spent less than 5 minutes to achieve successful radial artery cannulation, whereas 15 (100%) participants in the DP group spent less than 5 minutes to achieve successful cannulation.

In terms of complications, a haematoma was found in 7 of 30 (23.3%) patients in the GW group and in 11 of 30 (36.6%) patients in the DP group. There was no significant difference between the two groups.

Discussion

In this study, the guidewire-assisted radial artery cannulation technique increased the overall success rate among inexperienced trainees from 50–90%. Additionally, the first-attempt cannulation success rate was significantly higher with the guidewire-assisted technique than with direct arterial puncture.

The process of cannulation requires delicate and fine-tuned hand movements. Previous studies have shown low cannulation success rates in trainees with minimal or no experience ranging from 34.0–38.6%. [5, 10] Theoretically, learning how to perform radial artery cannulation is a psychomotor skill that requires a certain amount of practice and supervisor feedback to achieve success and gain experience. Thus, previous studies have shown that radial artery cannulation with the direct puncture technique performed by experienced clinicians has higher success rates ranging from 56.4–82.0% depending on various factors such as the vessel size, catheter type, and performer's experience. [11, 12] During a training program, every trainee must practice to gain more experience with radial artery cannulation; however, this

practice may involve either multiple cannulation attempts or failure, leading to procedure-related complications such as haematomas, vasospasm, infection, or vessel thrombosis.[13]

For inexperienced trainees, the determining factors of successful radial artery cannulation are identification of the appropriate puncture site of the radial artery and railroading the catheter into the artery. Therefore, new techniques and various equipment and tools have been developed to facilitate easier and faster radial artery cannulation. Beginners might not be confident with the artery palpation technique and may thus encounter difficulties in identification of the radial artery puncture site. This may result in misalignment of the puncture point over the radial artery. Moreover, the radial artery has a very small diameter at the level of the wrist (average diameter of 2.25–2.32 mm).[14, 15] The outer diameter of a 20-G catheter, which is the standard size for radial artery cannulation in adults, is 1.1 mm. Consequently, this procedure is often difficult for inexperienced trainees. Ultrasonography is very useful for visualisation of the vessel underneath the body surface for visual projection instead of palpation. Previous studies have used ultrasound guidance to locate the position of the radial artery. However, Zhefeng et al.[16] found no benefit of ultrasound-guided puncture. They showed that the use of traditional real-time ultrasonic localisation of the artery by inexperienced trainees produced a cannulation success rate of only 34.2%.[16] Another study involving senior anesthesiology residents who performed ultrasound-guided versus landmark-palpation radial artery cannulation showed no significant difference in the success rate between the two techniques (78% vs. 82%, respectively).[12] This authors stated that the lack of a significant difference could be explained by the learning curve of ultrasound-guided cannulation, which was a state-of-the-art and unfamiliar technique. In contrast, a recent study showed that ultrasound guidance increased the first-attempt success rate but not the overall cannulation success rate when compared with digital palpation.[3] As mentioned above, the ultrasound-guided technique facilitates precise visualisation of the artery location. However, the success rate of radial artery cannulation with ultrasound guidance was low and unsatisfactory. The present study involved participants who were inexperienced in radial artery cannulation and had been trained only by watching media or practicing on manikins. Nevertheless, this study showed that the effectiveness of watching short video media which demonstrated the steps of procedure in group of surgical residents would be sufficient for the performers. The success rate was higher in the guidewire-assisted group, which may be explained by the last step of radial artery cannulation (i.e., advancement of the catheter into the vessel). Beards et al.[9] noted that failure to cannulate the artery using the direct puncture technique commonly resulted from an inability to successfully advance the catheter despite the fact that the needle appeared to be within the artery. Additionally, studies involving paediatric patients showed that advancing the catheter after arterial wall penetration was more difficult than localisation of the artery.[17, 18] Mangar et al.[6] suggested that the causes of failure were tangential orientation of the catheter in relation to the artery, tortuosity of the vessel, and arterial vasospasm. In such cases, a guidewire can serve as a stent to facilitate advancement of the catheter through the skin and subcutaneous tissue and into the blood vessel.

In the present study, the overall procedural performance time was shorter in the guidewire-assisted group. Our study protocol allowed the participant trainees to perform two radial artery cannulation procedures

within 15 minutes; however, most of the successful cannulations (either guidewire-assisted or by the direct puncture technique) occurred within the first 5 minutes. Because our facility is a teaching hospital, we balanced the need for the trainees to practice cannulation skills and the risk of injury to patients or a long procedure time. Therefore, the practice time for radial artery cannulation by inexperienced trainees was expected to be 5 to 10 minutes. Even in a study comparing ultrasound-guided radial artery cannulation, which is a newer technique, versus the direct puncture technique at different levels of residency training, most of the successful cannulations required less than 5 minutes. [5]

Our study has several limitations. Inevitably, there was some effect of first-time experience on arterial cannulation to the second performance in anesthesiology residents. This study could not know or assess the individual operators' learning experience from the prior cannulation. Secondly, our study did not evaluate the comprehensive assessment after our manikin-based training and watching video media in anesthesiology residents. The lack of understanding of the task affects on acquisition of procedural skills.[19] Lastly, we did not have a simulator training of radial artery cannulation in surgical residents. The success rate of cannulation might be altered in performers who have an effective procedural skill training.

Conclusion

Guidewire-assisted radial artery cannulation showed a significantly higher success rate and shorter procedural performance time. Guidewire-assisted radial artery cannulation has advantages over direct arterial puncture when performed by inexperienced trainees.

Abbreviations

ASA: American Society of Anesthesiologists

BMI: Body mass index

IQR: Interquartile range

mmHg: Millimetre of mercury

mm: Millimetre

SD: Standard deviation

Declarations

Ethics approval and consent to participate

The study was approved by ethics committee of Ramathibodi Hospital, Mahidol University, Bangkok, Thailand (ID 046125). Informed consent was obtained from all participants in the trial. The trial was

retrospectively registered on Thai Clinical Trials Registry (TCTR20200601004). Date of registration was January 19, 2020. A late registration did not result in any changes in the study protocol.

http://www.thaiclinicaltrials.org/page_user/#

Consent for publication

Not applicable

Availability of data and materials

All the data used and/or analyzed are available from the corresponding authors upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Contributions

WA processed data clearance, data analysis, data interpretation and drafted the manuscript, NB participated in designing and coordinating the study, IS contributed to data collection, prepared figures and tables, PL contributed to the study design and revised the manuscript. All author read and approved the final manuscript.

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Figures

Figure 1

Kaplan–Meier curve of cumulative success rate. DP, direct arterial puncture, GW, guidewire-assisted cannulation