Original Article

A comparison of the success rate of radial artery cannulation between the ultrasound-guided and conventional palpation techniques in elderly patients undergoing cardiothoracic surgery

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ABSTRACT

Background: Ultrasound-guided (USG) radial artery cannulation against the standard palpation technique increases the first attempt rate in both pediatric and adult patients. The objective of this study was to evaluate the benefits of USG versus the palpation technique in improving the first attempt rate in elderly patients.

Methods: The patients over 65 years of age were randomized to the USG or Palpation group. The radial artery identification in the USG group was performed with the aid of the Sonimage HS 1. In the Palpation group, the radial artery was identified by manual palpation. The operators were cardiothoracic anesthesiologists. Overall success was defined as cannulation completed within 10 min.

Results: Eighty patients (40 in each group) were recruited. The respective first attempt and overall success rate for the USG group were similar to the Palpation group ($P > 0.999$ and $P = 0.732$). The time to the first attempt and overall success were also similar ($P = 0.075$ and $P = 0.636$). The number of attempts, number of catheters used, and failure rates were similar between the groups ($P = 0.935$, $P = 0.938$, and $P = 0.723$). The number of successful cannulations within 10 min was similar for both the groups as categorized by the radial artery diameter ($P = 0.169$).

Conclusions: The USG did not increase the first attempt or overall success rate of radial artery cannulation in the elderly patients undergoing cardiothoracic surgery. The time to first attempt and overall success were similar between both the groups. The number of attempts and number of catheters used were similar between both groups.

Keywords: Cardiothoracic, complications, elderly, first attempt, palpation, radial artery cannulation, ultrasound-guided

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INTRODUCTION

Arterial cannulation is an invasive and common procedure for continuous blood pressure monitoring and repeated arterial blood sampling in the intensive care units, operating rooms, and emergency rooms. It usually has to be done during major surgeries such as neurosurgery, liver surgery, cardiothoracic surgery, and for patients in critical conditions. The radial artery is the most common site for arterial cannulation because it is superficial and there is a dual

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blood supply via the ulnar artery to the hand.[1] Radial artery cannulation can be difficult to perform, leading to repeated unsuccessful attempts, potentially causing complications such as temporary occlusion of the artery, hematoma, local infection, bleeding, sepsis, pseudoaneurysm, and permanent ischemic damage.[2]

The ultrasound-guided (USG) technique has emerged as an alternative that can help in difficult arterial cannulation.[1,3,4] Its advantages include visualization of landmarks, increasing the first attempt success rate, and reducing complications.[4] Two-dimensional USG for arterial cannulation comprises the short-axis out-of-plane (SAX) and the long-axis in-plane (LAX).[4] The SAX or transverse method visualizes adjacent structures while the LAX enables inspection of the longitudinal lumen and confirmation of the intraluminal catheter. LAX imaging is particularly useful for identifying tortuosity, atheromatous plaques, and difficulties with catheter insertion.[5] Many studies have shown the benefits of USG for radial artery cannulation. Two systematic reviews, including both pediatric and adult patients, concluded that USG significantly increased the first attempt success rate of radial artery cannulation, and reduced mean-attempts to success, mean-time to success, and occurrence of hematoma.[6,7] A recent systematic review including only adult patients concluded that USG increased the first attempt success rate with no difference in time to cannulate or the mean number of attempts.[8]

A substantial number of patients undergoing cardiothoracic surgery, especially those with ischemic heart disease, are elderly patients. The functional and structural changes in the arteries arise in the elderly.[9,10] The incidence of an abnormal angle between the radial artery and the skin's surface is significantly higher in the elderly. These changes may lead to difficulty in radial artery cannulation.[10] The benefits of using USG for radial artery cannulation have not yet been studied in an elderly population.

The purpose of our study was to compare the first attempt success rate of radial artery cannulation between the USG and conventional palpation techniques in elderly patients. The overall success rate (success within 10 min), time to first success, time to overall success, number of attempts, number of catheters used, and complications were evaluated. We hypothesized that the USG technique would increase the first attempt success rate of radial artery cannulation as well as improve time to success, and decrease the number of attempts and catheters used.

MATERIALS AND METHODS

The study was reviewed and approved by the Institutional Review Board (HE631207) on 10-June-2020 and registered at the Thai Clinical Trials Registry (TCTR20210402003). All the participants gave written informed consent before being recruited. The study was conducted as per the Declaration of Helsinki and the ICH GCP. This study was reported according to the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

Our study was a prospective randomized controlled trial. All the patients were randomized to the USG or Palpation group. Randomization was performed using a computer-generated in the block-of-4 list. The allocation sequence, kept in sealed envelopes, was prepared by a cardiothoracic anesthesia fellow before the first participant was recruited. The sealed envelopes were opened immediately before arterial cannulation.

The inclusion criteria were patients over 65 scheduled for elective cardiothoracic surgery under general anesthesia at Queen Sirikit Heart Center of the Northeast, Khon Kaen University, Khon Kaen, Thailand, who passed the modified Allen's test, and required radial arterial cannulation. The exclusion criteria were patients with contraindications for radial artery cannulation such as skin infection at the cannulation site; previous catheterization or trauma to the radial artery; or, severe hypotension.

All the patients were visited and preoperatively evaluated on the day before surgery. Allen's test was performed. The following data were recorded: sex, age, weight, height, blood pressure, heart rate, underlying disease, diagnosis, and planned operation.

On the day of the surgery, the patients were transferred to the cardiothoracic operating theater where intravenous access was established. The monitoring included an electrocardiogram, pulse oximetry, and non-invasive blood pressure. An anesthesiologist who did not perform the radial artery cannulation measured the radial artery diameter with a Sonimage HS 1 (Konica Minolta, Tokyo, Japan) using a linear 4–18 MHz probe in a SAX approach. We then injected 1% lidocaine 0.5 mL intradermally at the cannulation site over the radial artery about 10 min before the procedure. The wrist joint of the patient was extended to 45°—with a rolled towel for support to facilitate arterial cannulation—and taped to a board to maintain wrist extension. With a strictly aseptic technique, a standard 20 G × 32 mm Jelco® intravenous catheter (Smith Medical, Ashford, Kent, UK) was used to percutaneously

puncture the radial artery. After successful cannulation of the radial artery, the arterial catheter was immediately connected to a primed pressure transducer connected to a monitor and zeroed. The catheter was then secured to the skin with a sterile covering (Tegaderm®, 3M, St. Paul, Minnesota, USA) and the patient proceeded for further anesthetic management at the discretion of the attending anesthesiologists.

The radial artery identification in the USG group was performed with the aid of the Sonimage HS 1 in a SAX approach. In the Palpation group, the radial artery was identified by manual palpation of the radial artery pulse. The intravenous catheter was inserted at 30–45° to the skin until a flashback of blood was observed. The catheter was then fully advanced over the needle into the artery. An observer recorded the time from the start of the procedure to each endpoint, as well as the number of attempts, number of catheters used, and any complications.

The start of the procedure was defined as the start of the radial artery identification of each technique. The time to success was defined as the time begun with identification of the radial artery until cannulation was complete with adequate catheter insertion. The first attempt success was defined as the cannulation achievement after the first attempt. The overall success was defined as the cannulation achieved within 10 min after starting the procedure regardless of the number of attempts. The time to first attempt success was defined as the time required for cannulation success after the first attempt. The time to overall success was defined as the time to cannulation success regardless of the attempts within 10 min after starting the procedure. The number of attempts was counted as each skin puncture or needle withdrawal from the skin. The failure was defined as the cannulation success with multiple attempts which required more than 10 min after starting the procedure.

The primary outcome was the first attempt success rate of radial artery cannulation. The secondary outcomes included the overall success rate, time to first success, time to overall success, the number of attempts, the number of catheters used, and complications.

The patients were followed up for 24 h after the procedure by nurse anesthetists who were not present in the operating theater. The complications from the radial artery cannulation were recorded (e.g., hematoma, hemorrhage, temporary arterial spasm, arterial thrombosis, or nerve damage).

The operators in this study were cardiothoracic anesthesia fellows and staff who had more than 3 years experience and had performed both the palpation and USG techniques for radial cannulation more than 100 times each.

Although the anesthesiologists who performed the cannulation and data collectors could not be blinded, the data analyst was blinded to group allocation.

Statistical analysis

The sample size was calculated based on a previous study that showed a first attempt success rate of 96.6% with USG and 73.3% with palpation.[11] With 80% power and a level of significance of 5%, the sample size needed with an anticipated dropout rate of 15% was 40 patients per group. Continuous data were tested for Gaussian distribution using the Shapiro–Wilk's test. Data with a normal distribution were presented as means ± standard deviations (SD) and compared using the unpaired Student's *t*-test. Data with a non-Gaussian distribution were presented as medians (min-max) and compared using the Mann–Whitney U test. Categorical data were presented as numbers (%) and compared using Pearson's χ^2 or Fisher's exact test. The primary outcome was presented as a mean or median difference with a 95% confidence interval (CI). $P < 0.05$ was considered statistically significant. All data were analyzed using SPSS 23 (IBM, New York, USA).

RESULTS

Eighty patients were recruited between July and December 2020 with 40 in each group [Figure 1]. Both groups were similar with regard to sex, weight, height, body mass index, the American Society of Anesthesiologists (ASA) physical status, underlying diseases, diagnosis, and type of operation. The USG group had a smaller radial artery diameter compared to the Palpation group ($P = 0.008$) [Table 1].

The respective first attempt and overall success rate for both the groups were similar ($P > 0.999$ and $P = 0.732$). The respective time to first attempt as well as the overall success of the USG group were also similar to the Palpation group ($P = 0.075$ and $P = 0.636$). The number of attempts, number of catheters used, and failure rate were similar between both the groups ($P = 0.935$, $P = 0.938$, and $P = 0.723$) [Table 2].

The number of successful cannulations within 10 min, categorized by radial artery diameter of both the groups, was similar ($P = 0.169$) [Figure 2]. The only complication found in this study was a hematoma which was similar between the groups (USG group 6 patients (15%); Palpation group 7 patients (17.5%), $P = 0.762$).

Table 1: Baseline characteristics and clinical data of patients in both groups

Demographic data	USG (*n*=40)	Palpation (*n*=40)	*P*
Age (years)	72.1±5.3	70.8±5.5	0.293
Sex: Male	26 (65)	26 (65)	>0.999
Height (cm)	162.0±8.3	160.0±8.0	0.447
Weight (kg)	60.2±12.7	58.1±12.6	0.465
ASA physical status: 2/3	2 (5)/38 (95)	6 (15)/34 (85)	0.263
Underlying diseases			
Hypertension	32 (80)	33 (82.5)	0.775
Diabetes mellitus	11 (27.5)	11 (27.5)	>0.999
Dyslipidemia	30 (75)	29 (72.5)	0.799
Cerebrovascular disease	3 (7.5)	0 (0)	0.241
Atrial fibrillation	12 (30)	7 (17.5)	0.189
Diagnosis			0.611
Coronary artery disease	19 (47.5)	14 (35)	0.364
Valvular heart disease	14 (35)	17 (42.5)	0.647
Aortic aneurysm	4 (10)	3 (7.5)	>0.999
Lung disease	3 (7.5)	5 (12.5)	0.712
Pericardial disease	0 (0)	1 (2.5)	>0.999
Type of operation			0.511
Coronary artery bypass graft	13 (32.5)	9 (22.5)	0.453
Off-pump coronary artery bypass graft	6 (15)	5 (12.5)	>0.999
Valvular surgery	14 (35)	17 (42.5)	0.647
Endovascular surgery	4 (10)	4 (10)	>0.999
Lung surgery	3 (7.5)	5 (12.5)	0.712
Radial artery diameter (mm)	2.6±0.6	2.9±0.4	0.008

Values presented as mean±SD, *n* (%) USG: ultrasound-guided

Table 2: Outcomes of the study

Study result	USG (*n*=40)	Palpation (*n*=40)	Mean difference	95% CI	*P*
First attempt success	28 (70)	28 (70)			>0.999
Overall success within 10 min	36 (90)	35 (87.5)			0.723
Time to first attempt success (s)	30.2±17.6	20.4±22.4	9.8	−1.0 to 20.5	0.075
Time to overall success (s)	78.1±106.6	65.7±113.2	12.4	−39.6 to 64.4	0.636
Number of attempts					0.935
1 attempt	28 (70)	28 (70)			
2 attempts	5 (12.5)	6 (15)			
3 attempts	2 (5)	1 (2.5)			
>3 attempts	5 (12.5)	5 (12.5)			
Number of catheters used	1.7±1.5	1.7±1.4			0.938
Failure rate	4 (10)	5 (12.5)			>0.999

Values presented as median (range) or *n* (%) USG: ultrasound-guided

DISCUSSION

The current study revealed that in the elderly patients undergoing cardiothoracic surgery, USG did not improve the first attempt or overall success rate within 10 min of radial artery cannulation compared to the palpation technique. Our result is different from the conclusions of the two previous systematic reviews, one with 546 patients from 7 randomized controlled trials (RCTs) and one with 482 patients from 7 RCTs, which showed that USG significantly improved the first attempt success rate of radial artery cannulation.[6,7] This may be because of differences in the age groups of the recruited population. Those systematic reviews included both the pediatric and adult patients while our study recruited only elderly patients. When comparing our results with the other studies including only adult patients, there are two systemic reviews, one recruiting 1,895 adult patients from 10 RCTs and the other 2,432 adult patients from 12 RCTs. It was concluded that USG, compared with palpation, increased the first attempt success rate, and decreased the failure rate,[8,12] however, the cannulations in those studies were done by the anesthesia residents and staff—not by experienced cardiothoracic anesthesia fellows and staff as was the case in our study. The results of our study are similar to a study comparing USG with palpation for radial artery cannulation among experienced cardiac anesthesiologists, which revealed that USG did not affect the rate of the first attempt, failure, or hematoma formation.[13] Although the age group of the study was different from ours—adults versus elderly patients, the results were similar. The results suggest that the expertise of the anesthesiologists who perform the radial artery cannulation is the most important factor for the success of cannulation. Nonetheless,

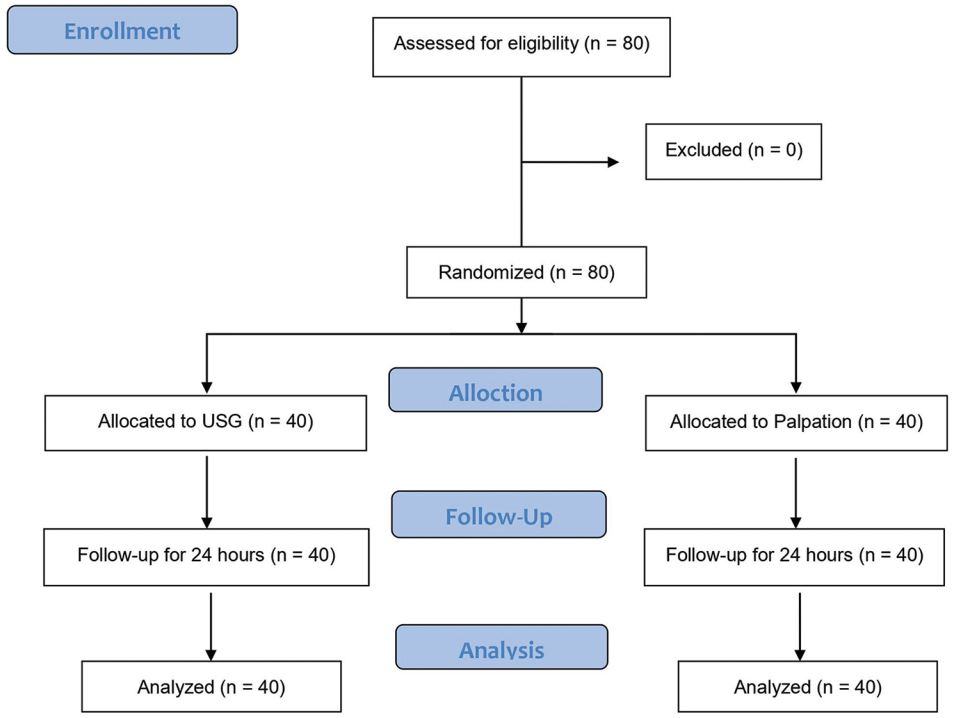

Figure 1: The CONSORT diagram of the study. USG: ultrasound-guided

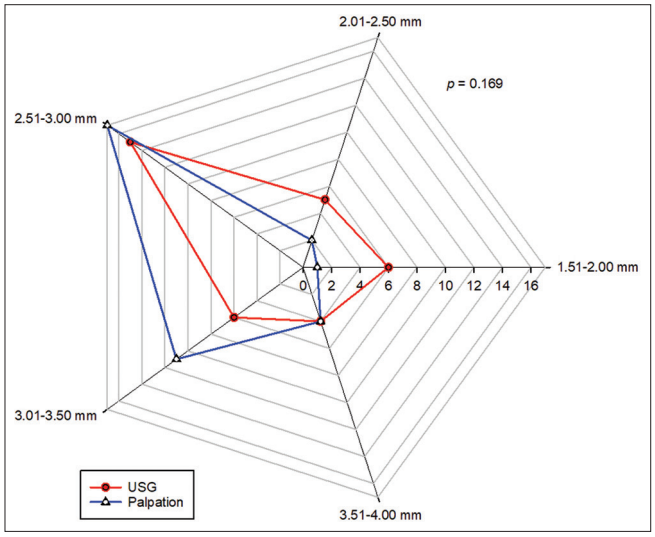

Figure 2: Number of successful cannulations within 10 min of patients in both groups categorized by radial artery diameter. USG: ultrasound-guided

in situations where the performer is a novice or lacks experience, a USG can improve first attempt success with a decreased cannulation time as well as fewer complications.

The time to first attempt as well as overall success were similar between both the groups; possibly because the performers in our study were cardiothoracic anesthesia personnel with expertise using the palpation technique, so the use of USG did not affect the cannulation time.

We included elderly patients because aging induces mechanical and structural changes to the vascular wall as well as a high incidence of the abnormal angle between the radial artery and skin surface. These changes result in reducing the success rate of radial artery cannulation, thus, USG was recommended for radial artery cannulation by anesthesiologists in elderly patients.[10] Nevertheless, our study showed that in the hands of experienced anesthesia specialists, USG did not increase the first attempt rate of radial artery cannulation in elderly patients.

We extended the wrist joint in our study to 45° to facilitate cannulation because a systematic review including 5 RCTs with 500 patients concluded that a 45° wrist angulation facilitated artery cannulation.[14]

A study demonstrated that LAX compared with SAX had a higher first attempt success rate with a shorter cannulation time and decreased complications.[15] Even though we used SAX to identify the radial artery, because we were more familiar with this approach, we recommend using the LAX for radial artery identification.

The radial artery diameter in our study ranged between 1.5 and 4.0 mm which is similar to a previous study (range, 1.0 and 3.4 mm).[10] The diameter of the radial artery in the USG group was smaller than that of the Palpation group ($P = 0.008$). A relatively smaller lumen may affect

the success rate of cannulation, however, no difference was found in the success rate of cannulation with respect to the size of the radial artery between both the groups [Figure 2] ($P = 0.169$). This may reveal the superiority of the USG technique in patients with a smaller radial artery.

The limitations of our study included (1) the operators of radial artery cannulation were experienced cardiothoracic anesthesia personnel, so the results of the study may not be generalized to novice or less experienced personnel. Further study vis-à-vis the latter population is suggested; (2) Ours was a single-center study with relatively small sample size, so a multi-center study with larger sample size is warranted; and (3) The patients in our study were normotensive, so further studies including hypotensive patients are recommended.

CONCLUSIONS

USG in the hands of experienced cardiothoracic anesthesiologists did not increase the first attempt or overall success rates of radial artery cannulation in elderly patients. The time to first attempt and overall success were similar between the groups. The number of attempts and number of catheters used were similar between the groups. No difference was found in the success rate vis-à-vis size of the radial artery. Since the USG group had a smaller radial artery diameter, the results may suggest the superiority of USG over the palpation technique in the elderly.

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Conflicts of interest

There are no conflicts of interest.

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