Longitudinal axis approach versus longitudinal oblique axis approach for ultrasound-guided radial artery cannulation in adult patients: A comparative study

Rakesh Kumar, Madhu Gupta, Parul Kaushik, Shyam Mohanan, Manisha Dabas

Department of Anaesthesia, ESIC Medical College and Post Graduate Institue of Medical Sciences and Research, Basaidarapur, New Delhi, India

Abstract

Background and Aims: Ultrasonography (USG)-guided arterial cannulation is a frequently performed procedure in the operating room and intensive care unit. Conventionally, longitudinal/in-plane and transverse/out-of-plane approaches are used for cannulation. Recently, a longitudinal oblique approach has been described with the advantage of wide visualization area. Hence, the present study was designed to compare the success of USG-guided radial artery cannulation in longitudinal oblique axis (LOA) and longitudinal axis (LA).

Material and Methods: Seventy patients requiring radial artery cannulation were randomly allocated into two groups: group L (USG-guided radial artery cannulation in LA) and group O (USG-guided radial artery cannulation in LOA). Primary outcome was to assess cannulation success in the first attempt, while the secondary outcomes were to assess the number of attempts, failure rate, total cannulation time, and associated complications.

Results: First-attempt success was higher in group O (80%) compared to group L (54.3%), with a *P* value of 0.022. In group L, 31.4% required two attempts and 5.7% had three attempts, while in group O, 14.3% had two attempts and 2.9% required three attempts. Group L failure rate was 8.6%, while it was 2.9% in group O. The mean total cannulation time (sec) for group L was 146.83 ± 89.37 and group O was 63.89 ± 26.277. No complication was observed with group O, while in group L, 9% had hematoma formation.

Conclusion: The LOA approach for USG-guided radial artery cannulation has higher first-pass success rate, total success rate, and requires less cannulation time compared to the LA approach.

Keywords: Approach, cannulation, complications, hematoma, radial artery, ultrasonography

Introduction

Arterial cannulation is a frequently performed invasive procedure in the operating room (OR) and intensive care unit (ICU) and is used for beat-to-beat hemodynamic monitoring, arterial blood gas analysis, and assessment of fluid responsiveness.[1-4] Arterial cannulation can be performed at various sites, including axillary, brachial, radial, ulnar, femoral, posterior tibial, and dorsalis pedis artery. Radial artery is the most commonly preferred site for cannulation, due to its superficial course and collateral blood supply in hand.[5]

Barr first described radial artery cannulation using a Teflon catheter with the palpatory method.[6] In 30% of individuals, there may be variation in the origin and course of radial artery, which increases the difficulty, more so in patients with obesity, hypotension, or edema.[3]

Address for correspondence: Dr. Parul Kaushik,
ESIC Medical College and Post Graduate Institue of Medical Sciences and Research, Basaidarapur, New Delhi - 110 015, India.
E-mail: drparulkg@gmail.com

Access this article online	
Quick Response Code:	Website: https://journals.lww.com/joacp
	DOI: 10.4103/joacp.joacp_275_23

How to cite this article: Kumar R, Gupta M, Kaushik P, Mohanan S, Dabas M. Longitudinal axis approach versus longitudinal oblique axis approach for ultrasound-guided radial artery cannulation in adult patients: A comparative study. J Anaesthesiol Clin Pharmacol 2024;40:504-9.

Submitted: 25-May-2023 **Revised:** 06-Nov-2023
Accepted: 06-Dec-2023 **Published:** 28-Mar-2024

With the advent of ultrasonography (USG), the success rate for cannulation has significantly improved. Ultrasound guidance for vascular access reduces the number of needle passes, time to cannulate, and incidence of associated complications.[7,8]

Conventionally, two approaches for USG-guided radial artery cannulation have been used: the transverse/out-of-plane approach and the longitudinal/in-plane approach.[9] The transverse approach (TA) offers broad image of the surrounding tissues and structures, thereby facilitating needle to reach the lumen of the artery. However, it is difficult to keep the needle tip within the USG beam, requiring frequent adjustment of the probe.[5]

Various studies suggest that the longitudinal approach (LA) is associated with comparable or greater first-pass success rate and relatively low complication, less time to cannulate, and low failure rate.[5] LA optimizes needle visualization, but it can be challenging to perform as the narrow width of USG beam makes it hard for the operator to keep the needle and nearby structures directly in the midline axis for visualization.[5,7] To overcome this difficulty, a relatively new longitudinal oblique axis (LOA) approach has been described, which has the advantage of a wider visualized area as in transverse view and direct needle visualization with reference to longitudinal view, while avoiding the section thickness artifact.[7,10,11]

The present study was conducted to compare the success of arterial cannulation with USG in LA and LOA. Our primary outcome was to assess the success of cannulation in the first attempt, while the secondary outcomes were to assess the number of attempts, failure rate, total cannulation time, and associated complications.

Material and Methods

This prospective randomized study was conducted in our institute after obtaining approval from the institutional ethical committee (IRB No. ESIPGIMSR-IEC/202000010), and participants were enrolled after Clinical Trials Registry of India (CTRI) registration (CTRI/2021/09/036555). The study followed the Good Clinical Practice guidelines and the principles of the Declaration of Helsinki (2013).

After obtaining written informed consent, 70 patients of either sex, aged 18–50 years, belonging to American Society of Anesthesiologists (ASA) physical status I/II, undergoing surgery, and having indication for radial artery cannulation were recruited for the study. Patient with negative modified Allen's test, anatomic variation of the radial artery, peripheral arterial disease, infection or burn at the site of insertion, and patients in shock were excluded from the study.

Computer-generated random numbers were used for randomization into two groups: group L (n = 35; USG-guided radial artery cannulation in LA) and group O (n = 35; USG-guided radial artery cannulation in LOA). Screening, randomization, concealment, and patient allocation were done using sequentially numbered sealed opaque slips by a fellow anesthesiologist unaware of the study.

Standard monitors including electrocardiography, noninvasive blood pressure, and pulse oximeter were attached. Patient was made to lay supine, with the arm placed on a flat armrest in moderate dorsiflexion (30°–45°), which was achieved by placing a towel under the dorsal aspect of wrist and the position maintained by taping the hand to the surface. Ensuring aseptic technique, scanning and cannulation were done with M-Turbo®R System Sono™ MB technology Fujifilm SonoSite portable ultrasound using a linear array transducer probe (6–13 Hz) of footprint 3.8 cm and a 20-G Becton Dickinson arterial cannula by an experienced anesthesiologist, who had placed more than 25 USG-guided arterial catheters.

In both groups, the USG probe was placed perpendicular to the artery, adjusting gain and depth for optimum visualization. Artery was identified as a circular anechoic pulsatile structure, confirmed by Doppler. Radial artery diameter (anteroposterior) and depth of anterior wall of artery from the skin were measured and the probe rotated 90° to place it parallel to the course of artery.

In group L, the artery was identified as a tubular, anechoic, pulsatile structure and rocking of probe was done to maximize the cross-sectional area [Figure 1]. Local anesthetic (LA) (Inj. 2% lignocaine) was administered and the arterial cannula was inserted on the midpoint of short axis of the USG probe at an angle of 30°–45° into the skin, under real-time guidance. Once the needle tip was visualized inside the artery and flash of blood was seen, the needle was lowered (10°–15°) and advanced 2–3 mm and the cannula was inserted into the artery and connected to a pressure transducer. Successful cannulation was confirmed by pressure waveform on the monitor.

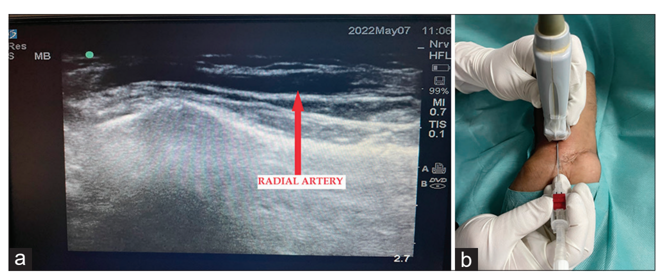

Figure 1: (a) Sonoanatomy of the radial artery in longitudinal axis approach (tubular in shape) with the ultrasound probe placed in alignment with the longitudinal axis of radial artery (right). (b) Arterial cannula inserted at the midpoint of short axis of the ultrasound probe

In group O, artery identification was similar to group L. Longitudinal axis view was obtained and the probe rotated at an angle of 15°–20° lateral (clockwise on the right hand or counterclockwise on the left hand). The elliptical artery was identified and probe rocking was done to maximize the cross-sectional area [Figure 2]. Arterial cannula was inserted on the midpoint of short axis of the USG probe at an angle of 30°–45° into the skin under real-time guidance and confirmation was done similar to group L.

In case of no backflow of blood, the cannula was withdrawn till the skin, redirected, and advanced until backflow was observed, which is defined as cannula redirection. In case of inability to cannulate even after redirection, the needle was removed and cannulation attempted again; this is defined as the second attempt. Inability to cannulate the artery after the third attempt is defined as failure. The primary outcome was to observe the success rate at the first attempt, while the secondary outcome was to note the total number of attempts and total cannulation time (time from first contact of the probe to appearance of waveforms on the monitor). Patients were observed for the next 48 h for complications like hematoma, thrombosis, or infection.

The sample size was determined based on the ability to perform successful radial artery cannulation in the first attempt. In the study of Zeng *et al*.,[7] 60 patients were randomly assigned to Oblique Axis-In-plane (OA-IP) group and Longitudinal Axis-In-plane (LA-IP) group and the study reported higher success rate of first attempt in the OA-IP group (93.3%) compared to the LA-IP group (60%). Taking this as reference, it was calculated that 32 patients in each group would provide a 90% power for detecting a significant difference at an alpha level of 0.05. However, 35 cases per group were enrolled during the study period.

The Statistical Package for Social Sciences (SPSS) program for Windows, version 17.0 (SPSS, Chicago, IL, USA) was used to perform statistical analysis. Continuous variables were presented as mean ± standard deviation (SD), and categorical variables as number and percentage. Normally distributed continuous variables were compared using the unpaired *t*-test. Nominal categorical data was compared using the Fisher's exact test, whereas non-nominal continuous variables were compared using the Mann–Whitney U test. $P < 0.05$ was considered statistically significant.

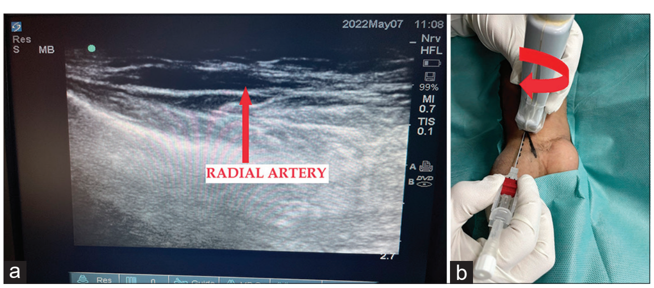

Figure 2: (a) Sonoanatomy of the radial artery in longitudinal oblique axis approach (elliptical in shape) with the ultrasound probe rotated at an angle of 15°–20° lateral, clockwise on the right hand. (b) Arterial cannula inserted at the midpoint of short axis of the ultrasound probe

Results

A total of 70 patients were randomized into two groups and they received the allocated intervention [Figure 3].

Patients' baseline demographics and clinical characteristics were found to be comparable in both the groups [Table 1].

Mean anteroposterior diameter and mean distance of radial artery from the skin showed no significant difference between the groups (*P* value 0.900 and 0.824, respectively) [Table 1].

Successful cannulation at the first attempt was found to be higher in group O compared to group L. Out of 35 patients in group O, 28 patients (80%) had successful cannulation in a single puncture compared to 19 patients (54.3%) in group L; the difference was statistically significant (*P* value 0.022] [Figure 4].

Total number of attempts taken for successful cannulation was lower in group O compared to group L [Table 2].

Out of the 70 patients, four patients, that is, one (2.9%) in group O and three (8.6%) in group L, could not be cannulated in three attempts (*P* value 0.614) [Figure 4].

The total cannulation time (sec) in group O was 63.89 ± 26.277 (mean ± SD) and in group L was 146.83 ± 89.37 (mean ± SD), with $P < 0.001$ [Table 2].

All the patients were observed for 48 h, wherein none of the patients in group O was observed to have any complications

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

Parameters	Group O (mean±SD)	Group L (mean±SD)	*P*
Age (years)	36.89±8.55	38.23±9.735	0.542
BMI (kg/m^2)	22.17±2.02	23.23±4.073	0.175
HR (/min)	78.2±6.31	79.37±6.992	0.464
SBP (mmHg)	124.71±5.322	125.89±6.961	0.216
DBP (mmHg)	83.09±5.517	83.77±6.054	0.622
ASA (I/II), *n* (%)	18/17 (%)	18/17 (%)	1.000
AP diameter (cm)	0.211±0.021	0.21±0.024	0.900
Distance from the skin (cm)	0.217±0.013	0.217±0.020	0.824

Data are presented as mean±SD or n (%). AP=Anteroposterior, ASA=American Society of Anesthesiologists, BMI=Body mass index, DBP=Diastolic blood pressure, HR=Heart rate, SBP=Systolic blood pressure, SD=Standard deviation

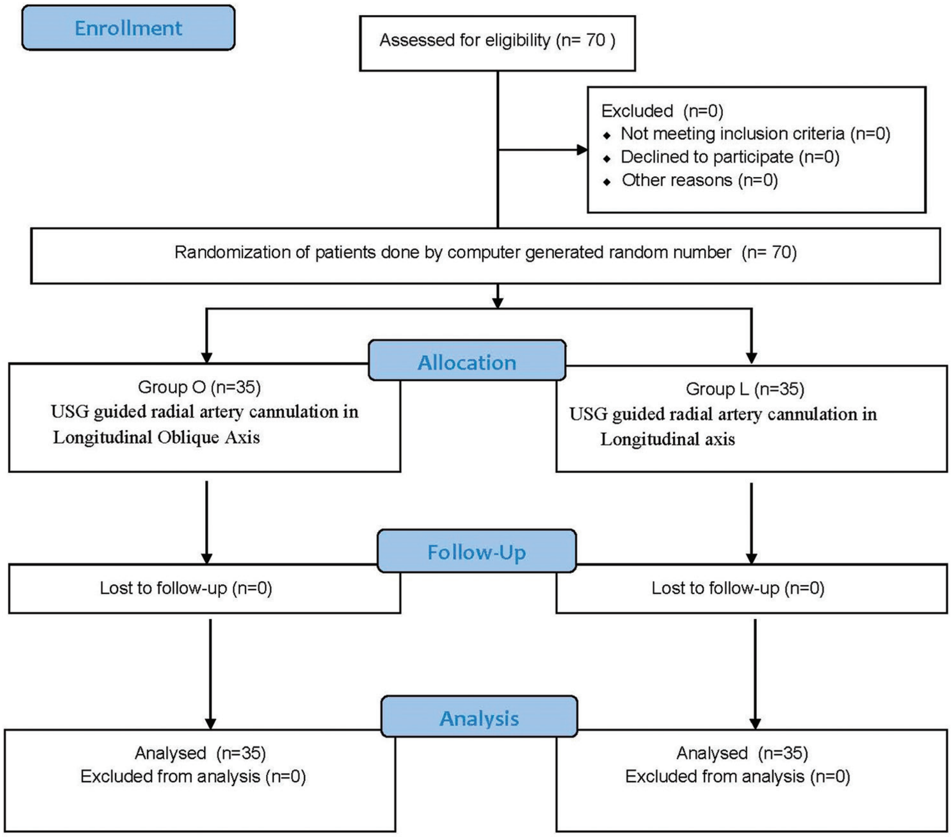

Figure 3: CONSORT flowchart. CONSORT = consolidated standards of reporting trials, USG = ultrasonography

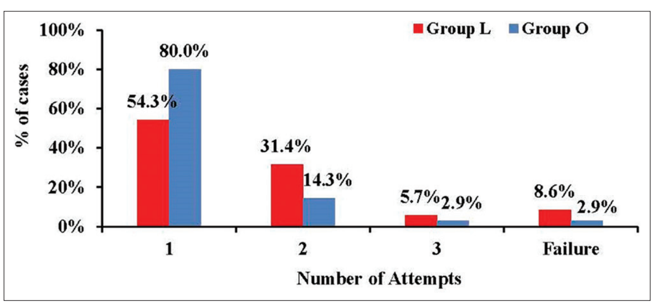

Figure 4: Bar graph depicting the frequency of number of attempts in group L and group O

Table 2: Comparison of the number of attempts and total cannulation time (sec)

Parameters	Frequency, *n* (%)		*P*
	Group O	Group L	
First	28 (80%)	19 (54.3)	0.022
Second	5 (14.3%)	11 (31.4%)	0.088
Third	1 (2.9%)	2 (5.7%)	1.000
Failure	1 (2.9%)	3 (8.6%)	0.614
Total cannulation time (sec)	63.89	146.83±89.37	<0.001

Data are presented as mean±SD or n (%). Failure: inability to cannulate the artery after the third attempt, total cannulation time: time from first contact of the probe to appearance of waveforms on the monitor. SD=Standard deviation

and three patients (9%) in group L had hematoma (*P* value 0.238).

Discussion

With adequate training, USG has shown to increase the success of radial artery cannulation with lesser complication, even in patients considered to have a difficult access.[8,12,13] Still, the overall success depends on adequate visualization of the artery and needle path in various planes, along with sufficient expertise in USG; hence, the comparison of in-plane and out-of-plane radial artery cannulation shows varying results in terms of first-attempt success and overall success. However, most of the studies show the long axis in-plane technique as either equivalent or having better success rate.[14-15] TA is associated with non-visualization of catheter while insertion and increased incidence of complications compared to LA. Lamperti *et al.*[16] recommended LA approach for USG-guided vascular access as it has better precision and lesser complication. Yet, with LA approach, a common problem faced while performing imaging is to keep the three, that is, the radial artery, ultrasound probe, and cannula, in one axis. To overcome this limitation, various modifications have been tried.[17,18] Hence, in the present study, we compared LA approach with LOA approach, which is a modification wherein after visualizing the radial artery in LA, the probe is rotated by 15°–20° and the artery is visualized as an elliptical structure [Figure 2]. This elliptical artery provides increased diameter, thus improving needle visualization, and renders more space for needle manipulation, simultaneously providing better overall stability. LOA also removes the section thickness artifact, which causes hindrance in LA.[10,11]

During our study, we additionally observed that keeping the hand (in which the probe is held) supported at elbow on a hard surface helps in maintaining stability while aligning all three axes, that is, USG probe, the radial artery, and cannula, thus improving overall success.

The results of our study are consistent with the studies of Abdalla *et al*.[1] and Zeng *et al*.,[7] where they also observed better first-attempt success rate in the oblique group than in the longitudinal group. The reason for low success in the longitudinal group could be the narrow width of the ultrasound beam and the section thickness artifact while using two-dimension ultrasound.[1,10,11]

In our study, the number of attempts to cannulate the radial artery was lesser in group O compared to group L, which could be attributed to better visualization of the artery and catheter pathway; this reflected an overall success rate of 97.1% in group O and 91.4% in group L. This observation was similar to the studies conducted by Zeng *et al*.[7] and Abdalla *et al*.,[1] which showed better overall success rate in LOA as compared to LA.[1,7] Lv *et al*.[14] conducted a meta-analysis and compared the long axis, short axis, and oblique axis for ultrasound-guided vascular access and found no substantial difference among the three in terms of total success rate and first-pass success rate. But this could be due to the fact that in their meta-analysis, oblique axis approach was reported only by one randomized controlled trial (RCT) which was not analyzed in detail and was done for internal jugular vein (IJV) cannulation.

Increased cannulation time in LA was observed probably due to more number of attempts taken in group L. Similar results were observed by Zeng *et al*.[7] and Abdalla *et al*.[1]

With increase in number of attempts, the complications such as vasospasm, hematoma, infection, and nerve injury also increase; however, with the help of USG, the anatomy of the target artery and its relationship with surrounding structures is well understood, thereby decreasing the likelihood of complications.[1,3,5,12,17,19] This emphasizes the importance of first-attempt success in arterial cannulation. In the present study, all patients were observed for 48 h, wherein no patient in group O had any complication and only three patients in group L had hematoma formation.

Our study had some limitations. It was done in a smaller group of patients comprising only ASA I and II adults. We did not include critically ill patients and pediatric patients in our study, hence the success rate and complications in these groups cannot be commented upon.

In conclusion, the LOA approach for USG-guided radial artery cannulation is superior to LA approach as it has significantly higher first-pass success rate, overall success rate, and requires less cannulation time.

Data availability

The data that support the findings of this study are available from the corresponding author, Dr. Parul Kaushik, upon reasonable request.

Signature: *Parul*

Name of the corresponding author: Dr. Parul Kaushik

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Abdalla UE, Elmaadawey A, Kandeel A. Oblique approach for ultrasound-guided radial artery catheterization vs transverse and longitudinal approaches, a randomized trial. J Clin Anesth 2017;36:98-101.
2. Kale SB, Ramalingam S. Spontaneous arterial catheter fracture and embolisation: Unpredicted complication. Indian J Anaesth 2017;61:505.
3. Sokhal N, Khandelwal A, Sokhal S, Chaturvedi A. Ultrasound-guided peripheral artery cannulation: A priority, not an option. Indian J Anaesth 2020;64:167-8.
4. Jain PN, Ranganathan P. Ultrasound in anaesthesia. Indian J Anaesth 2007;51:176-83.
5. Berk D, Gurkan Y, Kus A, Ulugol H, Solak M, Toker K. Ultrasound-guided radial arterial cannulation: Long axis/in-plane versus short axis/out-of-plane approaches? J Clin Monit Comput 2013;27:319-24.
6. Barr PO. Percutaneous puncture of the radial artery with a multi-purpose Teflon catheter for indwelling use. Acta Physiol Scand 1961;51:343-7.
7. Zeng CK, Zhao GF, Deng JH, Li DW. Oblique versus longitudinal axis/in-plane approaches for ultrasound-guided radial arterial cannulation: A randomised controlled trial. Eur J Anaesthesiol 2020;37:618-21.
8. Bai B, Tian Y, Zhang Y, Yu C, Huang Y. Dynamic needle tip positioning versus the angle-distance technique for ultrasound-guided radial artery cannulation in adults: A randomized controlled trial. BMC Anesthesiol 2020;20:1-8. doi: 10.1186/s12871-020-01152-1.
9. Sethi S, Maitra S, Saini V, Samra T, Malhotra SK. Comparison of short-axis out-of-plane versus long-axis in-plane ultrasound-guided

radial arterial cannulation in adult patients: A randomized controlled trial. J Anesth 2017;31:89-94.
10. Bertrand PB, Levine RA, Isselbacher EM, Vandervoort PM. Fact or artifact in two-dimensional echocardiography: Avoiding misdiagnosis and missed diagnosis. J Am Soc Echocardiogr 2016;29:381-91.
11. Goldstein A, Madrazo BL. Slice-thickness artifacts in gray-scale ultrasound. J Clin Ultrasound 1981;9:365-75.
12. Wilson C, Rose D, Kelen GD, Billioux V, Bright L. Comparison of ultrasound-guided vs traditional arterial cannulation by emergency medicine residents. West J Emerg Med 2020;21:353-8.
13. Kim SY, Kim KN, Jeong MA, Lee BS, Lim HJ. Ultrasound-guided dynamic needle tip positioning technique for radial artery cannulation in elderly patients: A prospective randomized controlled study. PLoS One 2021;16:e0251712. doi: 10.1371/journal.pone.0251712.
14. Lv Y, Liu H, Yu P, Wang G, Liu M, Li Y, *et al*. Evaluating the long-, short-, and oblique-axis approaches for ultrasound-guided vascular access cannulation. J Ultrasound Med 2019;38:347-55.
15. Liu L, Tan Y, Li S, Tian J. "Modified dynamic needle tip positioning" short-axis, out-of-plane, ultrasound-guided radial artery cannulation in neonates: A randomized controlled trial. Anesth Analg 2019;129:178-83.
16. Lamperti M, Bodenham AR, Pittiruti M, Blaivas M, Augoustides JG, Elbarbary M, *et al*. International evidence-based recommendations on ultrasound-guided vascular access. Intensive Care Med 2012;38:1105-17.
17. Hansen MA, Juhl-Olsen P, Thorn S, Frederiksen CA, Sloth E. Ultrasonography-guided radial artery catheterization is superior compared with the traditional palpation technique: A prospective, randomized, blinded, crossover study. Acta Anaesthesiol Scand 2014;58:446-52.
18. Wang J, Lai Z, Weng X, Lin Y, Wu G, Su J, *et al*. Modified long-axis in-plane ultrasound technique versus conventional palpation technique for radial arterial cannulation: A prospective randomized controlled trial. Medicine 2020;99:e18747. doi: 10.1097/MD.0000000000018747.
19. Kim SS, Han SH, Suh MG, Yu SC. Finger necrosis following percutaneous radial artery cannulation: A case report. Korean J Anesthesiol 2008;54:598-602.