Cerrahpaşa Med J 2023; 47(2): 176-181 ORIGINAL ARTICLE

Determination of Appropriate Artery Cannula Diameter by Measuring Radial Artery Diameters Using Ultrasonography and Investigation of the Correlation of "Allen Test" with Doppler Ultrasonography

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Abstract

Objective: We aimed to investigate the correlation of radial artery diameters with age, sex, height, and weight to determine a suitable size for cannulation and to assess the adequacy of the Allen test evaluating ulnar flow via ultrasonography.

Methods: A total of 500 patients with American Society of Anesthesiologists physical status I and II aged between 18 and 60 years without vascular pathology were enrolled. Allen test was performed at the nondominant hand, and radial artery diameter and ulnar artery flow were measured by ultrasonography before sedation. Measurements were repeated 5 minutes after anesthesia induction. Pearson's chi-square and Fisher's exact tests were used to compare categorical variables. Student's *t*-test and one-way analysis of variance test were used to compare continuous variables. Pearson correlation coefficient analysis was used to compare measurements. The statistical significance was accepted at a *P* value less than .05.

Results: The mean diameter of the radial artery was found smaller before (2.35 ± 0.39 mm) than after (2.57 ± 0.42 mm) anesthesia. The mean diameter of the radial artery was smaller in patients < 30 years of age than in the other groups before and after anesthesia. The mean diameter of the radial artery before anesthesia was smaller in normal and underweight patients than in the other groups and was smaller after anesthesia in underweight patients than in the other groups. The mean diameter of the radial artery in smokers before and after anesthesia was narrower in non-smokers. We did not find a relationship between ulnar blood flow and the Allen test.

Conclusion: Gender, height, weight, and age should be considered for proper radial arterial cannulation. Allen test may not be enough to show the ulnar flow.

Keywords: Artery cannulation, ultrasonography, Allen test

Introduction

Arterial cannulation is frequently used in anesthesiology and intensive care daily practice. Continuous pressure monitoring via arterial cannulation provides important information to the clinician about vital signs. It provides an easy way for blood sampling. Radial, ulnar, brachial, femoral, dorsalis pedis, and posterior tibial arteries are preferred for arterial cannulation.[1] Anatomically, the radial artery is preferred because of its ease of access, low risk of complications, and ease of procedure. Another reason for preferring the radial artery is that hand circulation can be provided alternatively from the ulnar artery in case of a complication that may develop during or after cannulation.[2]

During arterial cannulation, sufficient collateral circulation is essential to protect the distal tissue perfusion in case of thrombus formation. Allen test is a clinical screening test used to determine whether radial and ulnar arteries are sufficient for the hand's circulation.[3] It is an easy and practical test. But, it may give false-positive or false-negative results due to anomalies that are not clinically detectable and well-developed collaterals.[4]

The aim of this study was to determine the appropriate sized cannula for radial artery cannulation. Our second aim was to evaluate the adequacy of the Allen test to show ulnar flow by observing ulnar artery flow with Doppler ultrasonography (USG). In addition, we aimed to find out the relationship between radial artery diameter and age, gender, body mass index (BMI), and smoking.

Methods

After the approval of the İstanbul University-Cerrahpaşa, Cerrahpaşa School of Medicine Ethics Committee (Date: October 20, 2017, Number: 83045809-604.01.02). and written patient consent, the study was performed between November 2017 and March 2018 in Cerrahpaşa School of Medicine, Monobloc Operating Theater general surgery, urology, plastic reconstructive, and aesthetic surgery theaters. Five hundred thirty patients with American Society of Anesthesiologists (ASA) physical status I and

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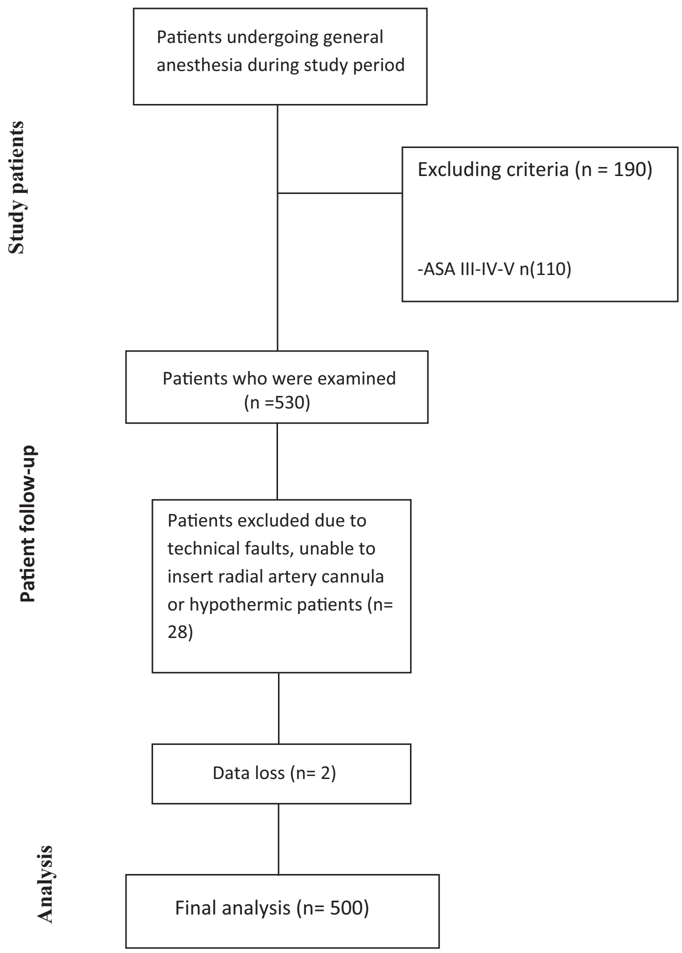

Figure 1. Flow chart.

II were examined, and 500 patients were included in the final statistical evaluation (Figure 1).

Patients with ASA III-V, any disease or condition that may cause hemodynamic instability or hypovolemia (ileus, colostomy, ileostomy, preoperative bowel cleansing, etc.), diabetes mellitus, hypertension, peripheral artery disease, coronary artery disease, hand or arm trauma, previous cannulation of the radial artery, patients with known radial and/or ulnar vascular pathology, Raynaud's phenomenon, and patients without consent were excluded from the study.

Patients were taken to the operating room after their informed consent was obtained. They were not sedated in order to keep cooperation required for Allen test. A standard ASA monitorization including a 3-lead electrocardiography, noninvasive blood pressure and peripheral arterial saturation (SpO_2) from the middle finger of the non-dominant hand were applied in the operating room. Age, sex, height, weight, ASA physical status, systemic disease, smoking history, BMI, body temperature, and thenar temperature of the non-dominant hand were measured and recorded in the study form. Body temperature was measured from the tympanic membrane, and the thenar temperature of the hand was measured with a skin probe. The thenar temperature was kept between 35°C and 35.5°C, and the tympanic temperature was kept between 36°C and 36.5°C during operation. We used forced air heaters during surgery to keep a constant temperature. The non-dominant hand of the patient was then extended to the arm board in anatomical position and the arm was fixed by placing a support under the wrist, with the wrist at 30° extension.

While the radial and ulnar arteries of the patient were pressured tightly at the wrist level, the patient was asked to release his/her hand after keeping the hand as a fist for 1 minute. The finger compressing the pressure of the ulnar artery was removed while the radial artery compression was maintained. A color change of less than 10 seconds was accepted as "normal Allen test" and a color change of longer than 10 seconds was accepted as "abnormal Allen test."[5]

Esaote My Lab 5 ultrasound (Esaote Europe B.V. Maastricht, Netherlands) with the LA523E 10 MHz probe was used for ultrasonographic measurements. The USG probe was placed transversely 2 cm proximal to the styloid process, and the short axes of the radial and ulnar arteries were separately visualized.[6] The diameter of the radial artery and the flow of the ulnar artery were measured and recorded. Allen test and ultrasonographic measurements were performed by the same physician (S.A.). She (S.A.) was trained in the Radiology Department for ultrasonographic measurements for 1 month before starting the study.

After the first measurements, midazolam 0.03 mg kg^{-1}, fentanyl 1-1.5 µg kg^{-1}, propofol 2 mg kg^{-1}, and rocuronium 0.6 mg kg^{-1} were administered and tracheal intubation was performed. End-tidal carbon dioxide and inhalation anesthesia were monitored following intubation. Sevoflurane 2% was used for the maintenance of anesthesia. Patients were ventilated with pressure-controlled mode by applying positive end-expiratory pressure of 6-8 cm H_2O at 12 frequencies per minute at the appropriate pressure providing 6-8 mL kg^{-1} tidal volume.

Five minutes after intubation body temperature was measured, and radial and ulnar USG measurements were performed again. All measurements were recorded in the study form. Radial artery cannulation was not performed before the measurements in any patient.

Statistical Analysis

We decided to include at least 460 patients for the study considering type 1 error 5% (bidirectional), type 2 error 5% (power 95%), and estimating a correlation between the radial artery and BMI variable (31) $r = 0.167$ ($P = .013$) with reference of a previous study.[7] Pearson's chi-square test and Fisher's exact test were used to compare categorical data. Paired samples *t*-test was used for the evaluation of the data which conforms to the normal distribution. The *t*-test and the one-way analysis of variance test were used for comparisons between the groups. Pearson correlation analysis was used for comparisons between measurements. Results were evaluated at a 95% confidence interval and $P < .05$ significance level. All analyses were conducted using NCSS 10.0 statistical software (2015, NCSS, LLC, Kaysville, UT, USA).

Results

Of the 500 study patients, 274 (54.8%) were female and 226 (45.2%) were male. The mean age of the patients was 42.12 ± 12.35 years, the mean height was 1.68 ± 0.09 m, the mean weight was 76.82 ± 17.34 kg, and the mean BMI was 27.38 ± 5.92 kg m^{-2}. One hundred five of the patients (21.0%) were under 30 years of age, 116 (23.2%) were 31-40 years old, 97 (19.4%) were 41-50 years old, and 182 (36.4%) were 51 years and older. Three hundred eighty-three (76.6%) patients were ASA I and 117 (23.4%) were ASA II. Fifteen patients (3.0%) were underweight, 149 (29.8%) were normal weighted, 199 (39.8%) were overweight, and 137 (27.4%) were obese. Two hundred twenty-one (44.2%) patients were previous or current smokers and 279 (55.8%) were non-smokers.

Table 1. Radial Artery Diameters According to Age

	30 Years and Below	31-40 Years	41-50 Years	51 Years and Above
Radial artery diameter before induction (mm ± SS)	2.21 ± 0.35	2.37 ± 0.41[*]	2.37 ± 0.37[ºγ]	2.42 ± 0.40[ΩϭΦ]
Radial artery diameter after induction (mm ± SS)	2.47 ± 0.39	2.61 ± 0.46[Ʊ]	2.57 ± 0.40[∞λ]	2.61 ± 0.44[φ¥ȣ]
	***P*1** < .001**	***P*1** < .001**	***P*1** < .001**	***P*1** < .001**

*P*1** < .05: statistically significant
***P*1**, radial artery diameters (RAD) before and after induction according to groups.
*RAD; 30 years and below compared to 31-40 years before induction (*P* = .002).
ºRAD; 30 years and below compared to 41-50 years before induction (*P* = .004).
ΩRAD; 30 years and below compared to 51 years and above before induction (*P* < .001).
γRAD; 31-40 years compared to 41-50 years before induction (*P* = .999).
ϭRAD; 31-40 years compared to 51 years and above before induction (*P* = .223).
ΦRAD; 41-50 years compared to 51 years and above before induction (*P* = .249).
ƱRAD; 30 years and below compared to 31-40 years after induction (*P* = .016).
∞RAD; 30 years and below compared to 41-50 years after induction (*P* = .095).
φRAD; 30 years and below compared to 51 years and above after induction (*P* = .007).
λRAD; 31-40 years compared to 41-50 years after induction (*P* = .508).
¥RAD; 31-40 years compared to 51 years and above after induction (*P* = .953).
ȣRAD; 41-50 years compared to 51 years and above after induction (*P* = .435).

Radial artery diameter increased after anesthesia induction compared to the pre-induction period (*P* < .001). In the pre-induction period, radial artery diameter was found to be the narrowest in patients 30 years old and younger (*P* = .002), while it was the widest over 51 years (*P* < .001) (Table 1).

The radial artery diameter of male patients was wider before induction compared to female ones (*P* < .001). Radial artery diameters were wider in both genders after anesthesia induction (*P* < .001) (Table 2).

Radial artery diameters increased after anesthesia induction in all groups when patients were categorized according to their BMI values (*P* < .001 for all groups) (Table 3).

The arterial diameter was found to be narrower in non-smokers before and after anesthesia induction compared to smokers (*P* < .001) (Table 4).

There was no correlation between the Allen test and ulnar artery blood flow before induction (Table 5).

We found a mild correlation between age and BMI when we evaluated the correlation between radial artery diameter and age, height, weight, and BMI of the patient before anesthesia induction (*r* = 0.21, *P* < .001; *r* = 0.17, *P* < .001, respectively). There was a modest correlation between radial artery diameter and height and weight (*r* = 0.40, *P* < .001; *r* = 0.36 *P* < .001) (Table 6).

We found a mild correlation between age and BMI when we evaluated the correlation between radial artery diameter and age, height, weight, and BMI of the patient after anesthesia induction (*r* = 0.11, *P* < .001; *r* = 0.12 *P* = .005). There was a modest correlation between radial artery diameter and height and weight (*r* = 0.42, *P* < .001; *r* = 0.32, *P* < .001) (Table 6).

There was a negative correlation between the change of radial artery diameter when measured before and after anesthesia induction and age, weight, and BMI (*r* = −0.18, *P* < .001; *r* = −0.01, *P* = .80; *r* = −0.08, *P* = .08). Weight and BMI were statistically insignificant. There was a mild correlation between the change in radial artery diameter and the height of the patients (*r* = 0.13, *P* = .005) (Table 6).

The thenar temperature of all patients was between 35°C and 35.5°C and tympanic temperatures were between 36°C and 36.5°C.

Discussion

Arterial cannulation may cause complications such as hematoma, bleeding, vasospasm, thrombosis, and necrosis of the extremity. The incidence of complications varies with the site of intervention, cannula size, and cannulation time.[8] Using a small size cannula for radial artery cannulation may reduce the number and duration of interventions for successful cannulation.[7] For these reasons, choosing the appropriate diameter cannula by predicting the diameter of the radial artery for cannulation is important.

In order to evaluate the safety of radial artery cannulation, Allen test is recommended to determine the collateral circulation of the ulnar artery.[5] Allen test may cause false-positive and false-negative results due to clinically unrecognizable anomalies and well-developed collaterals.

Lee et al[9] measured the radial artery diameters of 195 ASA I and II patients under anesthesia to determine the anatomical features of the radial arteries. They found that the mean value of radial artery diameter was 2.2 ± 0.4 mm. They found that the diameter

Table 2. Radial Artery Diameters According to Gender

	Female		Male		*T*	*P*1
Radial artery diameter before induction (mm ± SS)	2.17 ± 0.30		2.58 ± 0.37		−14.021	**<.001**
Radial artery diameter after induction (mm ± SS)	2.36 ± 0.33		2.82 ± 0.40		−14.138	**<.001**
	t = 20.9	***P*2* < .001**	*t* = 17.3	***P*2* < .001**		

**P* < .05: statistically significant.
P1, comparison of females to males before and after induction; P2, comparison of females to males before induction.

Table 3. Radial Artery Diameters According to Body Mass Index

	Underweight	Normal	Overweight	Obese
Radial artery diameter before induction (mm ± SS)	2.09 ± 0.30	2.29 ± 0.41*	2.38 ± 0.40[ºƱ]	2.42 ± 0.34[∞Ωα]
Radial artery diameter after induction (mm ± SS)	2.30 ± 0.39	2.54 ± 0.45[ȝ]	2.58 ± 0.44[Φʃ]	2.61 ± 0.38[φ¥ϭ]
	***P*1* < .001**	***P*1* < .001**	***P*1* < .001**	***P*1* < .001**

**P* < .05: statistically significant
*P*1, comparison of radial artery diameters according to BMI before and after induction.
*Radial artery diameters of underweight patients compared to normal weight before induction (*P* = .063).
[º]Radial artery diameters of underweight patients compared to overweight before induction (*P* = .005).
[∞]Radial artery diameters of underweight patients compared to obese ones before induction (*P* = .002).
[Ʊ]Radial artery diameters of normal weight patients compared to overweight before induction (*P* = .026).
[Ω]Radial artery diameters of normal patients compared to obese before induction (*P* = .003).
[α]Radial artery diameters of overweight patients compared to obese before induction (*P* = .340).
[ȝ]Radial artery diameters of underweight patients compared to normal weight after induction (*P* = .035).
[Φ]Radial artery diameters of underweight patients compared to overweight after induction (*P* = .013).
[φ]Radial artery diameters of underweight patients compared to obese after induction (*P* = .007).
[ʃ]Radial artery diameters of normal weight patients compared to overweight after induction (*P* = .383).
[¥]Radial artery diameters of normal-weight patients compared to obese after induction (*P* = .173).
[ϭ]Radial artery diameters of overweight patients compared to obese after induction (*P* = .547).

Table 4. Radial Artery Diameters According to Smoking Status

	Smokers	Non-Smokers	*P*1
Radial artery diameter before induction (mm)	2.45 ± 0.40	2.28 ± 0.37	**<.001**
Radial artery diameter after induction (mm)	2.67 ± 0.44	2.49 ± 0.40	**<.001**
	***P*2* < .001**	***P*2* < .001**	

**P* < .05 : statistically significant
*P*1, comparison of smokers and non-smokers before induction; *P*2, comparison of smokers and non-smokers before and after induction.

of the radial artery in all patients was wider than 0.9 mm which is the outer diameter of the 22G cannula. They found no statistically significant difference between the mean radial artery diameters according to age, sex, smoking, and presence of hypertension and diabetes mellitus.[9] In our study, we found the mean radial artery diameters are higher after induction compared to the pre-induction period. In all study patients, radial artery diameters were wider than the outer diameter of the 20G cannula (1.1 mm). We measured the narrowest radial artery diameter as 1.5 mm before anesthesia induction and 1.6 mm after induction. In the previous study,[9] unlike our study, they used alfentanil and desflurane for anesthesia induction and there were no measurements of the thenar temperature of the hand and body temperature. Patients included in the study may not be normothermic.[9] In addition, the study was conducted in South Korea, and the differences in diameter may be due to racial characteristics. In our study, radial artery diameters were found to be larger in males than females and in smokers compared to non-smokers. We think that the wider diameter in men depends on the structural characteristics. It is also wider in smokers which may be due to the decreased ability of vasoconstriction of the vessel in these patients.

Table 5. Correlation Between Allen Test and Ulnar Flow Before Induction

		Normal Allen Test		Abnormal Allen Test		
		n	%	n	%	*P*
Ulnar flow before induction	Yes	472	99.6	25	96.2	χ^2 = 4.846 ***P**** **= .148**
	No	2	0.4	1	3.8	

**P* > .005: statistically insignificant.

Dharma et al[10] examined the change in radial artery diameters and BMI of 1706 patients who underwent transradial catheterization for percutaneous coronary intervention. The measurements were made 1 day after the intervention. They reported that the study patients were from Indonesia, India, and Macedonia. The radial artery diameters measured before induction in the previous study[10] were wider compared to our study. They also reported that radial artery diameter was not correlated with BMI. However, they did not examine BMI into categories.[10] In our study, we found a poor correlation between radial artery diameter and BMI. When we categorized patients according to BMI, we found that the radial artery diameters measured before induction were larger in the overweight and obese patients than in the normal and underweight patients and that the radial artery diameters we measured after induction were larger in the normal, overweight, and obese patients than the underweight patients. This difference may be due to the vasoactive drugs used by the patients in the other study because of a history of coronary artery disease. It may also be due to differences in patient populations or racial characteristics. In the study of Dharma et al,[10] radial artery diameters in men were wider than in women, similar to our study.

The flow of fluids through an IV cannula is described by Poiseuille's law and is related to the viscosity of the fluid, the pressure gradient across the tubing, and the length and diameter of the

Table 6. Correlation of Radial Artery Diameter and Age, Length, Weight, and BMI

		Age	Length	Weight	BMI
Radial artery diameter before induction (n = 500)	*r*	0.21	0.40	0.36	0.17
	P	***<.001**	***<.001**	***<.001**	***<.001**
Radial artery diameter after induction (n = 500)	*r*	0.11	0.42	0.32	0.12
	P	***.011**	***<.001**	***<.001**	***.005**
Difference between radial artery diameter before and after induction (n = 500)	*r*	−0.18	0.13	−0.01	−0.08
	P	***<.001**	***.005**	****.80**	****.08**

*$P < .05$: statistically significant.
**$P > .05$: statistically insignificant.
BMI, body mass index.

tubing. The wider the cannula the faster the flow will be. For more precise and accurate pressure monitoring, wider cannulas are advised.[11] As a result of our study, we found out that the patients in the study group had an arterial diameter wider than 20G cannulas. This result in the study supports the use of appropriate cannula diameter, which gives more precise results in patients during pressure monitoring.

Kohonen et al[12] examined 145 patients who underwent coronary artery bypass grafting with radial artery grafting. They performed preoperative Allen test, Doppler ultrasonography, and finger plethysmography. In their study, they accepted that capillary filling should be longer than 6 seconds for an abnormal Allen test. They found an abnormal Allen test in 23% of the patients. They detected anatomical anomalies in 10 patients and circulatory insufficiency in 17 patients. Thirteen patients had both circulatory and anatomical problems. The sensitivity of the Allen test was 73.2%, and the specificity was 97.1%. Unhealing of the hand was not seen in any of the patients who received radial artery grafting. They suggested that the Allen test is a valuable screening test for the evaluation of hand circulation, If Allen test is negative, the radial artery may be used for grafting, but if the test is positive, further tests should be applied. The brachial artery divides into radial and ulnar arteries, and an extensive collateral network of superficial and deep palmar arteries connect the radial and ulnar circulations. However, in 58% of cases, the arch is incomplete.[13]

Allen's test is a simple bedside test used to assess blood flow to the hand. Despite the poor specificity of the test, it offers excellent sensitivity for the presence of a patent ulnar artery system. Any abnormalities need to be further evaluated using more sophisticated imaging modalities.[13]

In our study, the Allen test was abnormal in 5.2% of the patients. Kohonen et al[12] found a higher percentage of abnormal Allen test, which may be related to coronary artery disease in their study group and they accepted a cut-off value of 6 seconds for the abnormal Allen test result. In our study, we evaluated only ulnar flow with Doppler and found that ulnar flow was not correlated with the Allen test. In our study, the sensitivity and specificity of the Allen test were found to be 33.3% and 94.9%, respectively. The difference between the sensitivity and specificity of the 2 studies may be due to different patient groups and the cut-off value chosen for the abnormal Allen test.

We found that the radial artery diameters were larger after anesthesia induction than before induction due to the vasodilator effects of propofol and sevoflurane used in anesthesia induction and maintenance. Therefore, we think that radial artery cannulation may be performed more easily under general anesthesia.

We found that the radial artery diameter of the overweight and obese patients before anesthesia induction was wider than the normal and underweight patients and the radial artery diameter of the normal, overweight, and obese patients was wider than the underweight patients after induction. Radial artery cannulation is often difficult for obese patients because of the long distance between the skin and the artery lumen. Considering the larger diameter of the radial artery in obese patients, we suggest that a larger diameter 18G cannula with an external diameter of 1.3 mm may be more suitable for easier access to the radial artery.

In our study, the Allen test was abnormal in 26 patients (5.2%), but we found that only 1 of these 26 patients had no ulnar flow. Of the 474 (94.8%) patients with the normal Allen test, 2 had no ulnar flow. We found that there was no correlation between the Allen test and ulnar flow. This finding is concordant with recent studies.[14] Tousidonis et al[14] declared that clinical Allen test gives no further information about the palmar arch flow. The use of new technologies such as "photoplethysmography measurement"[15] for a more accurate assessment of collateral blood flow of the hand is encouraged. However, Allen test is still used as a screening test to assess collateral blood flow in case of a requirement for intra-arterial cannulation, even if it represents a weak correlation with Doppler USG.[16] Our study results are consistent with the previous studies showing a poor correlation between the Allen test and Doppler USG.[14-16] The accuracy of the Allen test which requires patient cooperation is also controversial. Accurate compression during testing is difficult and may cause different results. We believe that the Allen test may not be a sufficient test to evaluate the circulation of the hand.

Conclusion

In conclusion, when determining the cannula size for radial artery cannulation, the gender, height, weight, BMI, and age of the patients should be taken into consideration. A 20G cannula may be used in patients with ASA class I and II and without vascular pathology. Allen test may be insufficient to show ulnar flow in patients without vascular pathology, and we believe Allen test may not be a necessity to perform radial artery cannulation.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of İstanbul University-Cerrahpaşa, Cerrahpaşa School of Medicine (Date: October 20, 2017, Number: 83045809-604.01.02).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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