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Effect of the lateral tilt position on femoral vein cross-sectional area in anesthetized adults

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Background: A lateral tilt position can affect the size of the femoral vein (FV) due to increased venous blood volume in the dependent side of the body.

Methods: Forty-two patients, aged 20–60 years, were enrolled in this study. The cross-sectional area (CSA), anteroposterior, and transverse diameters of the FV were measured 1 cm below the left inguinal line using ultrasound. The value of each parameter was recorded in the following four positions: (1) supine, (2) supine + 10° left-lateral tilt (LLT), (3) 10° reverse Trendelenburg (RT), and (4) RT + LLT.

Results: CSAs of the left FV in the supine, supine + LLT, RT, RT + LLT positions were 0.93 ± 0.22 , 1.11 ± 0.29 , 1.17 ± 0.29 , and $1.31 \pm 0.32 \text{ cm}^2$, respectively. Compared to the supine position, there was a significant increase in CSA and anteroposterior diameter according to the three changed positions. The transverse diameter of the left FV was significantly increased in supine + LLT, RT, RT + LLT positions compared to that in the supine position ($P = 0.010$, $P = 0.043$, $P = 0.001$, respectively). There was no significant difference in the transverse diameter of the left FV between the supine + LLT and RT positions ($P = 1.000$).

Conclusions: Adding LLT to the supine and RT positions increased the CSA of the unilateral FV significantly.

Keywords: Catheterization; Femoral vein; Posture; Ultrasonography.

INTRODUCTION

Femoral vein (FV) catheterization can be used in emergency situations for administering fluids and drugs and measuring central venous pressure [1]. In addition, FV catheterization may be performed in patients with suspected massive bleeding during surgery and in those in whom accessing peripheral blood vessels is difficult [2].

The success rate of central venous catheterization (CVC) is correlated with the size of the target vessel [3]. Theoretically, increasing the exposure of FV may also be helpful in success-

ful FV catheterization. Increased exposure of FV is possible by increasing the cross-sectional area (CSA) and diameter of FV while reducing the overlap of the FV and femoral artery (FA). To maximize CSA of the FV, the reverse Trendelenburg (RT) position and Valsalva method have been investigated [4,5]. Abduction and external rotation of the leg have also been studied to reduce the overlap of the FV and FA [6,7]. Changing a patient's position by lateral tilting to the left or right is commonly performed during surgery. These position changes can also affect the size of the ipsilateral FV by increasing venous blood volume on the dependent side of the body.

However, no studies have examined the correlation between the size of the FV and the lateral tilt position.

In this study, we hypothesized that adding a lateral tilt position would increase the size of the ipsilateral FV and investigated the effect of the left lateral tilt (LLT) position on CSA and the size of the FV in the supine and RT positions using ultrasound.

MATERIALS AND METHODS

Patients

This study was approved by the Hospital Ethics Committee of the Kosin University Gospel Hospital (KUGH 2017-03-019), and informed consent was obtained. The study group consisted of patients with American Society of Anesthesiologists physical status class I–II, aged 20–60 years who were scheduled for general anesthesia for elective gynecological or urological surgery. Patients with a previous history of inguinal surgery or procedure, deep vein thrombosis, and vascular disease were excluded. We also excluded patients with a history of hypertension, hypotension, congestive heart failure, renal or lung disease, obesity (body mass index > 30 kg/m²), or pregnancy.

Anesthesia and monitoring

All patients fasted for more than 8 hours and entered the operating room without pretreatment. After entering the operating room, patients were monitored using noninvasive blood pressure, electrocardiography, and pulse oximetry. Patients received 5 ml/kg of lactated Ringer's solution over 5 minutes. For induction of anesthesia, midazolam 0.05 mg/kg, propofol 1 mg/kg, and remifentanyl 1.0 µg/kg were administered intravenously until completion of endotracheal intubation. Rocuronium 0.8 mg/kg was administered for muscle relaxation, and intubation was performed 90 seconds after treatment. After intubation, mechanical ventilation was started using a tidal volume of 6–8 ml/kg at 40% oxygen. The respiratory rate was adjusted to maintain the end-tidal CO₂ value at 35–40 mmHg. Sevoflurane 1.0–1.5 vol% and remifentanyl were continuously administered to maintain anesthesia.

Data acquisition and recording

After induction of anesthesia, the left FA and FV of the patient were confirmed using ultrasound (Vivid, GE Medical Systems Israel Ltd., Israel), and the measurements were performed 1 cm below the left inguinal line. Based on previous studies that showed that the frog-leg position increased the size and exposure of the patient's FV [7], all measurements were performed in this position. The frog-leg position can be achieved by abduction and external rotation of the hip joint with knee flexion. Using an 8 MHz two-dimensional linear transducer, the following values were measured in a short axis view of the FV using the built-in caliper without compressing the patient's measurement site: (1) CSA, (2) anteroposterior diameter, (3) transverse diameter, and (4) non-overlapping transverse diameter of the FV (Fig. 1). The non-overlapping transverse diameter of the FV was measured by subtracting the arterial overlap from the transverse diameter of the FV.

The above values were measured in the following four positions: (1) supine, (2) supine + 10° LLT, (3) 10° RT, and (4) 10° RT + LLT.

A protractor (Saehan Tester Co., Korea) was used to establish the 10° position change of the patient. Each position change was maintained for at least 30 seconds to reflect

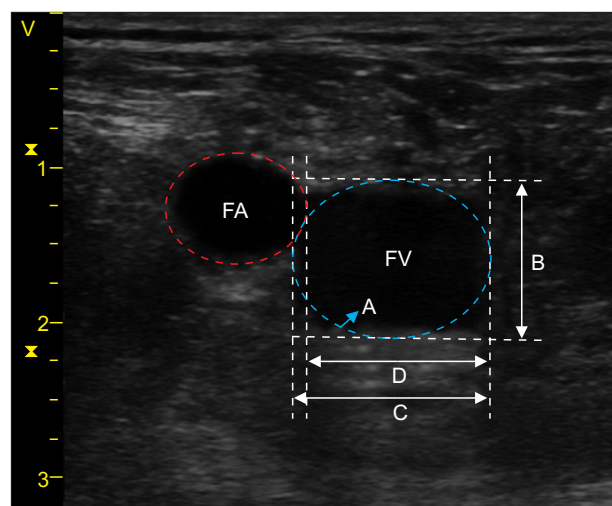


Fig. 1. Depiction of the measurements performed for the left femoral artery (FA) and femoral vein (FV) on ultrasound images. A: cross-sectional area. B: anteroposterior diameter of the FV. C: transverse diameter of the left FV. D: non-overlapping transverse diameter of the left FV.

changes in blood volume due to the change in position. Subsequently, the measurement was performed using ultrasound. To ensure the maximum size and accurate measurements of the FV, one anesthesiologist who is skilled in ultrasound image acquisition saved ultrasound images at the end of inhalation. Each measurement was then recorded in agreement with another anesthesiologist.

Statistical analysis

A previous study showed that CSA of the FV measured in the supine position was $0.85 \pm 0.41 \text{ cm}^2$ [4]. For the present study, we determined that 42 subjects ($\alpha = 0.05$, power 0.8) would be required to observe a statistically significant change in CSA of the FV by $> 20\%$ in the LLT position.

All statistical analyses were performed using IBM SPSS (version 24.0, IBM Corp., USA). Tests for normality of all measurements except for sex were performed using the Shapiro-Wilk test. Repeated measures of analysis of variance with correction by the Bonferroni method for multiple comparisons were used to evaluate the change in CSA, anteroposterior diameter, transverse diameter, and non-overlapping transverse diameter of the left FV according to the position change. The sphericity assumption was performed by Mauchly's test, and the Greenhouse-Geisser correction was applied. A P value of < 0.05 was considered significant.

RESULTS

A total of 42 patients completed the study, and no patients were excluded due to hemodynamic instability. Patient demographic data are shown in Table 1.

CSAs of the left FV in the supine, supine + LLT, RT, and RT + LLT positions were 0.93 ± 0.22 , 1.11 ± 0.29 , 1.17 ± 0.29 , and $1.31 \pm 0.32 \text{ cm}^2$, respectively (Table 2). Compared to the supine position, CSAs of the three changed positions were significantly increased (all $P < 0.001$). When changing from the supine to the supine + LLT position, CSA of the left FV was increased by 19.6%. However, compared to the RT position, CSA of the left FV in the RT + LLT position was increased by 12.4%.

The anteroposterior diameters of the left FV in the supine, supine + LLT, RT, and RT + LLT positions were 10.2 ± 1.2 , 10.9 ± 1.4 , 11.6 ± 1.5 , and $12.3 \pm 1.8 \text{ mm}$, respectively. Compared to the supine position, the anteroposterior diameters of the three changed positions were also significantly increased (Table 2).

Table 1. Demographic Data of Patients

Variable	Value
Age (yr)	49 ± 13
Sex (M/F)	20/22
Weight (kg)	63.7 ± 10.2
Height (cm)	163.2 ± 7.7
Body mass index (kg/m^2)	24.4 ± 3.1

Values are presented as mean \pm SD or number.

Table 2. Comparison of the Diameter and Cross-sectional Area of the Left Femoral Vein

Variable	Supine	Supine + LLT	RT	RT + LLT
Cross-sectional area (cm^2)	0.93 ± 0.22 (0.86–1.00)	$1.11 \pm 0.29^*$ (1.0–1.20)	$1.17 \pm 0.29^{*,\dagger}$ (1.08–1.26)	$1.31 \pm 0.32^{*,\dagger,\ddagger}$ (1.21–1.41)
Mean increase of the cross-sectional area (%)		$19.6 \pm 12.8^*$ (15.6–23.3)	$25.9 \pm 14.0^{*,\dagger}$ (21.1–29.5)	$42.1 \pm 17.8^{*,\dagger,\ddagger}$ (35.6–46.2)
Anteroposterior diameter (mm)	10.2 ± 1.2 (9.8–10.6)	$10.9 \pm 1.4^*$ (10.5–11.4)	$11.6 \pm 1.5^{*,\dagger}$ (11.1–12.1)	$12.3 \pm 1.8^{*,\dagger,\ddagger}$ (11.8–12.9)
Transverse diameter (mm)	11.5 ± 1.4 (11.0–11.9)	$12.4 \pm 2.2^*$ (11.7–13.0)	$12.2 \pm 2.0^*$ (11.6–12.8)	$13.2 \pm 2.1^{*,\dagger,\ddagger}$ (12.5–13.8)
Non-overlapping transverse diameter (mm)	9.5 ± 2.5 (8.7–10.3)	$10.3 \pm 3.1^*$ (9.3–11.3)	10.1 ± 2.3 (9.4–10.8)	$10.7 \pm 2.4^{*,\ddagger}$ (10.0–11.4)

Values are presented as mean \pm SD (95% confidence interval). Supine: supine position, Supine + LLT: supine + 10° left-lateral tilt position. RT: 10° reverse Trendelenburg position, RT + LLT: 10° RT + 10° left-lateral tilt position. Anteroposterior diameter: anteroposterior diameter of the left femoral vein (FV). Transverse diameter: transverse diameter of the left FV, Non-overlapping transverse diameter: transverse diameter of the FV not overlapping the femoral artery. $^*P < 0.05$ compared with the supine position. $^\dagger P < 0.05$ compared with the Supine + LLT. $^\ddagger P < 0.05$ compared with the RT.

The transverse diameters of the left FV were 11.5 ± 1.4 , 12.4 ± 2.2 , 12.2 ± 2.0 , and 13.2 ± 2.1 mm in the supine, supine + LLT, RT, and RT + LLT positions, respectively (Table 2). The transverse diameter was significantly increased in the supine + LLT, RT, and RT + LLT positions compared to the supine position ($P = 0.010$, $P = 0.043$, $P = 0.001$, respectively). There was no significant difference between the transverse diameter of the left FV in the supine + LLT and RT positions ($P = 1.000$).

The non-overlapping transverse diameters of the left FV were 9.5 ± 2.5 , 10.3 ± 3.1 , 10.0 ± 2.3 , and 10.7 ± 2.4 mm in the supine, supine + LLT, RT, and RT + LLT positions, respectively (Table 2). Compared to the supine position, there was a significant increase in the non-overlapping transverse diameters of the left FV in the supine + LLT ($P = 0.004$) and RT + LLT positions ($P < 0.001$). However, there was no significant difference between the supine and RT positions ($P = 0.264$).

DISCUSSION

In this study, we found that the size of the FV significantly increased when a lateral tilt was added to both the supine and RT positions.

The RT position used in this study is one of the most common positions during surgery. RT positioning for FV catheterization is used to change the size of the FV by instantaneously increasing blood flow to the lower part of the patient. Stone et al. [4] reported a 55% increase in the CSA of the FV in adults upon changing to a 15° RT position from the supine position. Likewise, in young children, a 15° RT position increased the CSA of the FV by 25% compared to the supine position [8]. In the present study, CSA of the FV measured in the 10° RT position increased by 25.9% compared to that in the supine position and by 42.1% when LLT was added to the 10° RT position. Despite the results indicating statistical significance, CSA of the FV in the 10° RT + LLT position increased by only 12.4% compared to the 10° RT position, suggesting that the increase may not have clinical implications in terms of additional application of LLT in the RT position. However, compared to measurement values in the supine position, CSA of the FV was increased more in the RT + LLT position than in the RT position. This change is thought to be due to the addition of the left and right blood flow difference in the body due to the left tilt position, and therefore, CSA of the FV on

the tilted side is considered to be further increased compared to the RT position only. The fact that the FV, which is already increased by the RT position, can be increased by adding the right or left tilt position may be useful for practitioner during CVC through the FV.

The size of the FV significantly increased by tilting the patient to the left in the supine as well as RT position. In this study, the CSA and the anteroposterior diameter of the left FV were larger in the RT position than in the supine + LLT position. However, the transverse diameter and non-overlapping transverse diameter of the left FV were not different between the supine + LLT and RT positions. This means that when CVC is performed using the FV, the FV can be enlarged by laterally tilting the patient from the supine position to the practitioner's side without the RT position. Furthermore, in emergency situations during surgery, CVC requires a higher rate of successful and faster catheterization than in relatively stable situations. In addition, in the case of blood loss due to massive bleeding, a complication frequently encountered by anesthesiologists during surgery, practitioners can be hesitant to use the RT position due to the risk of a sudden decrease in cerebral blood pressure [9]. Likewise, previous studies have shown that the Valsalva method, which can also be used to increase the size of the FV, also has the potential to cause a decrease in blood pressure due to a sudden decrease in heart preload [10]. Therefore, if head elevation is not appropriate or is difficult to perform, our result that the size and diameter of the FV can be increased by tilting the patient to the left or right or the practitioner's side in the supine position may be helpful for the anesthesiologist.

In most patients, the FV is somewhat overlapped by the FA. This overlap can lead to accidental arterial puncture during FV catheterization. In this study, all measurements were performed in the frog leg position that can be achieved by abduction and external rotation of the hip joint with knee flexion. This is based on previous studies in which the frog-leg position was found to increase the CSA and diameter of the FV [7]. In the present study, the addition of LLT increased the non-overlapping transverse diameter of the FV. However, the overlapping transverse diameter of the FV also increased with the position change. When the FA and FV overlap to some extent, the FV becomes larger overall as the position changes, and overlapping of the FV by the FA is also increased. Thus, when attempting catheterization perpendicular to the skin,

the practitioner should consider that the increase in the transverse diameter of the non-overlapping FV with the position change is not as large as the total change in the FV.

In clinical practice, because of catheter-related thrombosis and infection, the internal jugular vein or subclavian vein is more commonly used as the CVC site than the FV [11–13]. However, during surgery on the head and thorax region, rapid access to catheterization sites such as the internal jugular or subclavian vein is difficult. In these emergencies, the FV may be cannulated temporarily to administer large fluid volumes or drugs. In addition, FV catheterization can be used to measure the pressure of the FV during liver transplantation anesthesia or when extra-corporeal membrane oxygenation is required [14–17]. Recently, ultrasound has been widely used and FV catheterization can be performed with direct confirmation. The use of ultrasound can help to reduce unnecessary arterial puncture and subsequent hematoma formation, as well as increase the success rate of the catheterization [12,18,19]. Nevertheless, ultrasound is not used for all CVC [20–22]. In particular, in a study conducted in the United States, it was reported that only 45% of practitioners use ultrasound for FV catheterization [23]. CVC, including FV catheterization, may be necessary even in the absence of ultrasound. Thus, changes in the size of the FV according to the position changes confirmed in this study may be helpful for FV catheterization, regardless of the use of ultrasound.

This study has some limitations. First, we did not obscure the purpose of this study from the anesthesiologist who measured the size of the FV. However, to ensure the accuracy of the measurements, we employed another anesthesiologist experienced in ultrasound equipment to confirm the results before recording the final measurements. Second, we did not evaluate whether the LLT position increased the success rate of FV catheterization in patients. Although the size of the FV changed significantly with postural changes, additional clinical studies are needed to determine whether these changes correlate with a decrease in the number of needle attempts and an increase in the success rate of FV catheterization.

In conclusion, the present study demonstrated that the size of the FV significantly increased by adding LLT to patients in the supine and RT positions.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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