Determination of the optimal position of the lower extremity for femoral nerve block with ultrasonographic measurements: a prospective volunteer-based study

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Abstract. – **OBJECTIVE:** The aim of the study was to determine the optimal position for femoral nerve block (FNB) under ultrasound guidance.

PATIENTS AND METHODS: We included fifty volunteers between 18-65 years of age in this study. The distances from the skin to the landmarks, which were taken as a reference for the ultrasound-guided FNB (apex point of the femoral artery = F12, lateral point = F9, and lower point = F6), were measured and compared in 3 different positions given to the lower extremity (neutral position: P1, 45° abduction: P2, and flexed knee: P3). The ease of application and the quality of the ultrasound images were evaluated at each measurement by assigning a subjective observer score and comparing them in three positions.

RESULTS: All three measurement points were found to be closest to the skin at position P3. However, the distances from F9 ($p = 0.023$) and F6 ($p = 0.006$) to the skin were significant. A significant difference was found between P1 and P3 in terms of the distance from F9 ($p = 0.027$) and F6 to the skin ($p = 0.007$). P3 was determined to be the position with the highest score for clarity of the ultrasonography images and ease of detection of the measurement points ($p < 0.001$). As the scores of ease of access to the femoral nerve (FN) and image clarity increased, the distance from the measurement point to the skin surface decreased, which was statistically significant.

CONCLUSIONS: The ideal position for ultrasound-guided FNB is the P3 position. As an alternative for patients with limited mobility, the P2 position can be used.

Key Words:
Femoral nerve, Ultrasound-guided, Nerve block, Lower extremity, Femoral artery.

Introduction

Peripheral nerve blocks (PNBs) are widely used to induce anesthesia and postoperative analgesia. PNBs offer distinct advantages over general or neuraxial anesthesia in certain clinical situations[1]. The advantage of PNBs is providing analgesia while reducing opioid use in patients of advanced age, frailty, and comorbid diseases, especially by preventing respiratory side effects and complications[2]. Instead of traditional block techniques, ultrasonographic visualization guidance is combined with the standard nerve stimulation technique to prevent complications[3,4]. In this way, direct visualization of the distribution of local anesthetics using high-frequency probes can prevent complications stemming from lower/upper extremity nerve blocks. For the success of PNB under ultrasound guidance, it is critical to ensure that the distribution of the anesthetic used is in the optimal dose and amount around the nerve to be blocked. Ultrasonography guidance enables the anesthetist to maintain accurate positioning of the needle and monitor local anesthetic distribution in real time[4]. Ultrasonographic imaging of anatomical structures is a method that provides safe blocks of superior quality with optimal needle positioning. Additionally, by directly monitoring the distribution, the amount of local anesthetic can be minimized, and an effective block can be achieved[5].

PNBs of the lower extremities are used for operative anesthesia and/or postoperative analgesia in various lower extremity surgeries. Ultrasonography is more difficult with lower extremity blocks. PNBs of the lower extremities are used for

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operative anesthesia and/or postoperative analgesia in various lower extremity surgeries. Ultrasonography is more difficult with lower extremity blocks. Imaging nerve structures in the lower extremities may be more difficult, for example, in the gluteal and subgluteal regions, where the sciatic nerve is thin, wide, and deep. This is due to the deeper penetration of the nerve within the muscle and the distribution of its branches, as well as the anatomical neighborhood of the nerves to bone structures. Bone structures make imaging of the nerve difficult. Image resolution and quality can become quite limited as penetration depth increases. The sciatic nerve has a relatively superficial distribution in the femoral and gluteal regions[6,7]. A femoral nerve block (FNB) is used to induce anesthesia and/or postoperative analgesia in knee and anterior thigh surgeries. According to the American Society of Anesthesiologists Classification, FNB is among the various regional anesthesia techniques for the lower extremities commonly employed in patients with a risk score of three or higher. FNB aims to reduce the risks and complications related to anesthesia. It targets patient-anesthesiologist-surgeon comfort and the early mobilization of patients. As with all PNBs, potential complications (e.g., local anesthetic toxicity, hematoma and vascular puncture, nerve tissue injury) and quadriceps muscle weakness have been linked with FNB. However, the superficial location of the femoral nerve (FN) in the inguinal fold and its distance from the spinal cord and vital organs make FNB a relatively well-tolerated PNB[8,9].

As with many nerve blocks, ultrasonography is frequently used to increase the effectiveness of FNB and reduce the incidence of potential complications. The relationship between the ease of application of the FNB, visibility of the FN, and visibility of the femoral artery (FA) in different positioning of the lower extremity is crucial when FNB is applied. Although most recent studies[10-12] focus on the technical aspects of PNBs, only a few[13-16] focus on optimal positioning and angulation of the patient and the extremity in the area where the block is to be applied. The aim of the study is to draw attention to this lack of information and to determine the most suitable bodily position of the tissue, which is primarily superficial and can be done quickly for an FNB without complications under ultrasound guidance. In addition, we aim to evaluate the relative positions of the FN and FA at different lateral rotation angles of the lower extremity and to determine the positioning of the lower extremity that ensures the least damage to the vascular nerve package in the location where an FNB is to be performed.

Patients and Methods

Ethics Approval

After receiving the approval of the local ethics committee (Ethics Committee of Harran University, Decision No. HRU/20.02.15) for our study, a total of 50 volunteers aged 18-65 were recruited for the study. Written informed consent was obtained from the volunteers. Additionally, all participants included in the study signed informed consent for the use of images.

Study Population and Data Sources

This study is a volunteer-based cross-over prospective study, and all volunteers who met the inclusion criteria were included in the study. The exclusion criteria were as follows: individuals who underwent surgery near the FA and/or in the inguinal region, individuals with burns or trauma, individuals with an active infection in the region where the ultrasonography probe was placed, individuals under 18 and over 65 years of age, individuals with a body mass index (BMI) of >35, individuals with limited abduction and limited adduction with rotation in the femoral region and lower extremity. Volunteers without these exclusion criteria were included in the study. The study was conducted in the anesthesiology and reanimation clinic of Harran University Hospital. A 10-18 MHz MyLab 30Gold ultrasonography linear probe (Esaote, Florence, Italy) was inserted transversely into the inguinal fold with the patient in the supine position. After visualizing the FA, femoral vein, and nerve bundle from the lower inguinal region, the distance between skin and the apex of the FA (12 o'clock, F12), the lateral point of the FA (9 o'clock, F9), and the lower point of the FA (6 o'clock, F6) were measured (Figure 1). These measurements were made with the patient in three different positions: when the thigh is aligned with the midline of the body (P1 = neutral position: 0°), when the thigh is abducted 45° away from the midline (P2 = 45° abduction), and when the calcaneus is placed on the patella of the other thigh (P3 = flexed knee) (Figure 2). To avoid narrowing the vessels, no pressure was applied to the ultrasonography probe during the measurements. To visualize the FN, the ultrasonography probe was guided lightly in the cranial or caudal directions. The distance between

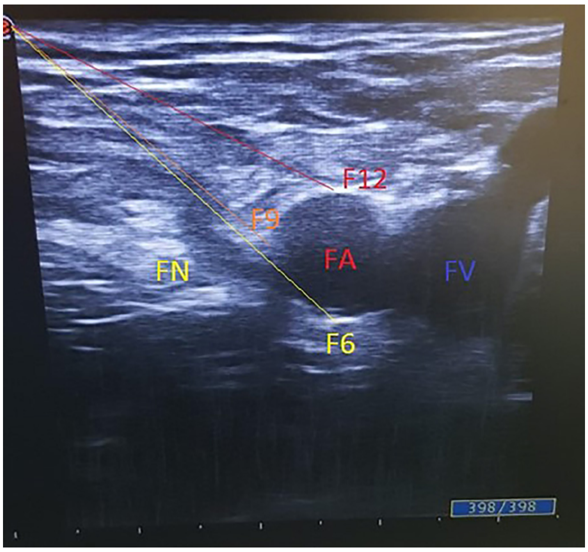

Figure 1. Anatomical structures and Landmarks in ultrasound imaging. (FA) Femoral artery. (FV) Femoral vein. (FN) Femoral nerve. (F12) The distance between skin and the apex of the FA. (F9) The distance between skin and the lateral point of the FA. (F6) The distance between skin and the lower point of the FA.

the point indicated by the light of the probe on the ultrasonography image and the aforementioned points around the FA was measured (Figure 1). Distance measurements from different points of the FA to the skin surface were compared with the ultrasonography image sharpness score. The measurements were made and recorded by the same anesthetist, an expert with more than 10 years of anesthesia experience. Based on the clarity of the ultrasonography image and the ease of detection of the measurement points, an evaluation score of between 1 and 5 points (1 = very bad, 2 = bad, 3 = mediocre, 4 = good, 5 = very good) was assigned by the anesthetist performing the measurements; the assigned score for each position was recorded. The results were also confirmed by another anesthesiologist researcher with at least 10 years of experience.

Statistical Analysis

Windows-compatible IBM SPSS Statistics software version 20.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. One-way analysis of variance (ANOVA) was used for between-group comparisons, and the Bonferroni test was used for post-hoc analysis of homogeneously distributed variances. Based on the F6 (the distance between the skin and the lower point of the FA) values, post-hoc power analysis for 50 patients was calculated as 1.00 of 0.05 error margin and 1.247 effect. Power analysis was performed using G*Power (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The correlation between ultrasonographic image scores and the distances of F12, F9, and F6 to the skin was evaluated by Pearson correlation analysis. Categorical variables were expressed as counts and percentages, and continuous variables were expressed as mean and standard deviation (SD). For the analysis results, $p < 0.05$ was evaluated as statistically significant.

Figure 2. Lower extremity positions that can be used in femoral nerve block and the location of the ultrasound probe. (P1) neutral position: 0°. (P2) 45° abduction. (P3) flexed knee. Participants gave permission to use the photos for this article.

Results

Fifty male volunteers with an average age of 27.06 ± 7.47 (min. 18-max. 51) years, an average height of 173.48 ± 5.49 cm (range: 160-184 cm), and an average weight of 73.26 ± 6.80 kg (range: 58-85 kg) were recruited to the study.

The distances from the skin to the three different points of the FA (F6, F9, and F12) when the lower extremities are in the P1, P2, and P3 positions are shown in Table I. It was determined that all three measurement points were closest to the skin in the P3 position.

Based on the results we obtained, it was determined that the average distance from the measurement points to the skin was the farthest in the P1 position. Although these distances were shorter in the P2 position and P3 position than in the P1 position, the distance from F12 to the skin was not statistically significant ($p = 0.057$). However, the distances from F9 ($p = 0.023$) and F6 ($p = 0.006$) to the skin were significant. There was a statistically significant difference between P1 and P3 in terms of the distance from F9 to the skin ($p = 0.027$) and the distance from F6 to the skin ($p = 0.007$) according to the Bonferroni post-hoc test.

The statistics of the evaluation scores for the clarity of the ultrasonography image and ease of detection of the points F12, F9, and F6 at different positions of the lower extremity are given in Table II. Based on these scores, it was determined that P3 was the position with the highest score for clarity of the ultrasonography images and ease of detection of the measurement points ($p < 0.001$).

Based on the results of the Pearson correlation analysis used to evaluate the correlation between the evaluation scores and the distance to the skin surface from F6, F9, and F12, a negative correlation was found between the scoring and the distances ($p < 0.05$). It was observed that the scores for image clarity and ease of access to the FN increased as the distance from the measurement point to the skin surface decreased (Table III).

Discussion

With the development and widespread use of ultrasonography, its use and importance in anesthesia practices is gradually increasing. It is frequently preferred especially in arterial and venous cannulation, perioperative fluid management and regional anesthesia applications. Ultrasonography has been reported to increase overall success rates for cannulation and reduce complication rates. The use of ultrasonography is important for practitioners in reducing morbidity and mortality in regional anesthesia applications and in applications requiring deep sedation[17-19].

FNB is the most commonly applied lower extremity nerve block[20], and is used in hip, knee, and anterior thigh surgeries – especially in complicated cases involving elderly patients in which positioning is difficult. FNB is used because it reduces adverse effects, improves positioning, and provides effective analgesia that lowers analgesic and opioid use. FNB can be used alone or in combination with other blocks, depending on the indication[21]; it can be applied before a central neuraxial block. It is performed preoperatively for these procedures but may also be useful for postoperative analgesia or the treatment of acute pain in acute injuries. In addition, it also contrib-

Table I. Descriptive statistics of the distance between the skin and the measurement points for the femoral artery for different positions of the extremity.

Measurement points for the femoral artery	Extremity position	Mean ± SD*	p (Anova)		p (Bonferroni)
F12: The distance between skin and the apex of the FA (12 o'clock)	P1	20.31 ± 5.55	0.057^{α}	P1-P2	0.207^{β}
	P2	18.40 ± 4.12		P2-P3	$>0.99^{\beta}$
	P3	17.93 ± 4.96		P3-P1	0.072^{β}
F9: The distance between skin and the lateral point of the FA (9 o'clock)	P1	22.37 ± 4.94	0.023^{α}	P1-P2	0.117^{β}
	P2	20.35 ± 4.70		P2-P3	$>0.99^{\beta}$
	P3	19.80 ± 4.93		P3-P1	0.027^{β}
F6: The distance between skin and the lower point of the FA (6 o'clock)	P1	26.87 ± 5.53	0.006^{α}	P1-P2	0.052^{β}
	P2	24.43 ± 4.76		P2-P3	$>0.99^{\beta}$
	P3	23.71 ± 4.87		P3-P1	0.007^{β}

SD, Standard Deviation; P1, Neutral position; P2, 45° abduction; P3, Flexed knee; FA, femoral artery. *Millimeter, $^{\alpha}$Anova, Analysis of Variance, $^{\beta}$Bonferroni test.

Table II. Descriptive statistics of ultrasound image sharpness scores for different extremity positioning and ease of detection of measurement points.

Extremity position	Min.	Max.	Mean ± SD*	*p* (Anova)	*p* (Bonferroni)	
Neutral position (P1)	1	3	1.70 ± 0.67	<0.001[α]	P1-P2	<0.001[β]
45° abduction (P2)	1	4	2.58 ± 0.85		P2-P3	<0.001[β]
Flexed knee (P3)	2	5	3.76 ± 0.77		P3-P1	<0.001[β]

SD, Standard Deviation. *Millimeter, [α]Anova, Analysis of Variance, [β]Bonferroni test.

utes to shortening hospital discharge times. Although the relative depth of the FN may vary, its most superficial application is at the level of the inguinal fold (expected depth of 2-4 cm)[21,22]. The FNB is ideal with a high frequency (>10 MHz) linear probe ultrasonography guidance because of the relatively superficial location of the FN. The FN is typically located in a triangular hyperechoic region lateral to the FA and superficial to the iliopsoas muscle[20]. Because of its pulse and/or flow, which can be determined using Doppler ultrasound, the location of the FA relative to the nerve is easily determined. Therefore, in our study, the FA was used as a marker to determine the location of the FN. The objective is to be able to inject a local anesthetic solution into the area adjacent to the FN to achieve a successful nerve block.

Ultrasonography guidance allows for a reduction of the effective dose of the local anesthetic required through a highly precise injection. A prior study[22] reported that the distance between the FN and the FA is related to the patient's age. Therefore, for ultrasound-guided FNB, precise identification of the FN is essential[22], as there may be anatomical variations in the FN. Nerve stimulation may contribute to increasing the odds of success of the nerve block[22]. Positioning for surgery is difficult because of severe pain in the fractured limb; hence, regional techniques, such as the FNB and fascia iliaca block are used to reduce pain during positioning.

Very few studies on PNBs have focused on which patient position and angular orientation of the extremities is optimal to reach the nerve more easily[23]. Even if the nerve is superficial, optimal patient positioning is critical for the visualization of the nerve block needle and the nerve. A study by Zaragoza et al[10] demonstrates that as the angle of injection of the infraclavicular block increases, the clarity of the ultrasonographic image of the nerve increases. In the study of Wang et al[14], the distance at which the brachial plexus is closest to the skin and the lowest risk of pneumothorax from a brachial plexus block were investigated at different angles given to the arm. The effect of different positioning of the extremity on the success of a neural block was also investigated[16]. In a recent study[13], ultrasonography measurements from different levels were compared. The study investigated which bodily positions and what angular positioning of the extremity ensured particularly clear ultrasonography images and increased the applicability of the neural block, as well as the impact of each position on the success of the block[13]. Various new positions have been reported with different indications for the most ideal bodily position of the patient for ultrasound-guided PNBs[11,15]. When applying lower extremity nerve blocks under ultrasonography guidance, the leg and knee can be placed in various angular positioning[12]. However, we could not find any extant publication in the literature that provides

Table III. Correlation analysis of evaluation scores and the distances of F12, F9, and F6 to the skin.

		F12	F9	F6
Score	Pearson correlation	-0.184*	-0.202*	-0.234**
	p	0.024	0.013	0.004

F12: The distance between skin and the apex of the FA (12 o'clock); F9: The distance between skin and the lateral point of the FA (9 o'clock); F6: The distance between skin and the lower point of the FA (6 o'clock). *Statistically significant for correlation analyses at the 0.05 level, **Statistically significant for correlation analyses at the 0.01 level.

information on the optimal positioning of the patient and the extremity that maximizes the operator's access to the inguinal region and increases the odds of success of the FNB. It is still unclear what position and/or angulation should be applied to the thigh and leg during FNB. To our knowledge, our study is the first to compare bodily positions for ultrasound-guided FNB.

From the measurements in our study, we found that all three points of the FA were closest to the skin in the P3 position (Table I). We surmise that P3 is the most appropriate positioning of the extremity for performing ultrasound-guided FNB. If the patient has limited movement in that limb, we propose the P2 position as an alternative and are convinced it will facilitate FNB under ultrasound guidance.

When the ultrasonography image sharpness score was evaluated by the same experienced anesthesiologist, we also achieved the clearest image in the P3 position. Therefore, we surmise that ultrasound-guided FNB can be performed in the P3 position most easily. We obtained the second clearest image evaluation score in the P2 position, followed by the P1 position. Hence, we recommend the P2 position as an alternative position when performing ultrasound-guided FNB in cases in which the patient has a limited range of motion in the affected limb. Furthermore, we found that the evaluation score for image quality increased with a decrease in the distances of all three points of the FA from the skin, and that there is a strong correlation in this regard (Table III). For this reason, we surmise that when FNB is performed with ultrasonography, anatomical structures can be visualized more easily, and a high-quality safe nerve block can be made with optimal needle positioning. We believe it would be appropriate to support these findings with randomized clinical studies with larger sample sizes.

Limitations

The following are some of the limitations of this study: all participants had a normal BMI, only male volunteers agreed to participate in the study, and there were no patients with different diagnoses. Since the ultrasound was performed in the groin area, women did not volunteer due to privacy concerns, and the authors were unable to enroll a mixed population due to the unavailability of women to participate in the study. Our results should, therefore, also be confirmed in different genders.

Conclusions

In conclusion, the ideal position for ultrasound-guided FNB is supine position and the lower extremity in the P3 position. This improves the efficiency of the nerve block and lowers the risk of complications. We conclude that, in this position, the decisive points are closest to the skin and most clearly visible, and the vascular nerve bundle is least likely to be damaged. Additionally, for patients with limited mobility, the P2 position can be used as an alternative with the patient lying on their back.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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Ethics Approval

This study was approved by the Harran University Faculty of Medicine Clinical Research Ethics Committee (Approval Date: 27 January 2020, Session No. 02, HRU/20.02.15).

Informed Consent

Informed and written consent was obtained from all participants before the study.

Consent to Publication

Participants gave permission to use the photos for this article.

Authors' Contribution

Erdoğan Duran: designed the research, analyzed and interpreted the data, conducted the research, and prepared the article. Başak Pehlivan: reached the data, analyzed and interpreted the data. Firdevs Kaya: concept, design, literature review, critical review, resources. Veli Fahri Pehlivan: literature search, critical review, materials, and editing.

Data Availability

All data used in this study can be obtained from the corresponding author upon request.

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