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A Guideline for Femoral Nerve Block With the Age-Related Formulas Obtained From the Distances Between the Femoral Nerve and Surface Anatomical Landmarks in Fetal Cadavers

Una Guía para el Bloqueo del Nervio Femoral con Fórmulas Relacionadas con la Edad Obtenidas a Partir de las Distancias entre el Nervio Femoral y los Puntos de Referencia Anatómicos Superficiales en Cadáveres Fetales

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SUMMARY: The femoral nerve (FN) is used for nerve block in many surgeries and provides effective postoperative analgesics in the pediatric population. However, although there are sufficient anatomical maps and signs for femoral nerve blockades in adults, there is not enough information for the pediatric group. Therefore, in our study, we tried to determine an effective area for safe block blocking with the help of bone structures in order to perform effective blockade in younger age groups. The study was conducted on 60 lower limbs. The exit point of the FN was identified. The measurements were examined in two regards, namely the level of the FN and the relationship of the FN with the surrounding structures. For the right and left sides, all the parameters showed increases with age. A significant relationship was found between all the parameters of the fetal cadavers ($p<0.01$). It was determined that there was a strong correlation between all parameters related to FN and surrounding bone structures ($p<0.01$).Sex was not found to be significantly related to the other parameters ($p<0.05$ Among all the fetal cadavers, high-level division was observed in six limbs (10 %), mid-level division in 33 limbs (55 %), and lower-level division in 21 limbs (35 %). Gestational age-based regression equations from my study showed that the site of the blockage could be effectively performed with the aid of palpable bone structures from the outside without the need for technical assistance.

KEY WORDS: Femoral nerve; Regional anesthesia; Guideline; Infant; Variation; Microdissection.

INTRODUCTION

The femoral nerve (FN) represents the primary source of innervation for the anterior compartment of the thigh and the widest branch of the lumbar plexus (Astik & Dave, 2011; Jiji *et al*., 2012). In the case of lower limb injuries among the pediatric population, regional anesthesia is becoming more popular than general anesthesia due to its postoperative benefits. Although caudal blocks are still preferred after lower limb operations in young children and infants, peripheral blocks are actually superior to central nervous blocks in terms of both their long-term efficacy and the patient's postoperative rehabilitation (Simion & Suresh, 2007; Luo *et al*., 2015). A femoral nerve block is used in several surgeries due to its capacity to provide effective postoperative analgesia. FN block sallow for painless radiological examination and patient transfer due to exerting an analgesic effect on hip lateral rotation and flexion as well as knee flexion and extension. Additionally, FN blocks help with pain management during the postoperative period (Simion & Suresh).

Since the use of ultrasound-guided nerve blocks has increased in recent years, it is important to understand the superficial anatomical structures and their relations with the nerve block in detail in order to increase the surgical success rate, minimize nerve injuries, and provide an easy, comfortable and complete blockade without pain (Simion & Suresh; Turner *et al*., 2014). When compared with the situation in adults, the

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anatomical landmarks may prove difficult to identify in children during the developmental stage, it is important to recognize that if the specific surface anatomical structure is unknown in children, it may increase the risk of injuries to the FN and femoral artery (FA). This renders the application of peripheral nerve blocks difficult. Although the use of ultrasound-guided blocks would increase the success rate of the procedure, it may restrain block failure in the presence of an aberrant FN anatomy. In addition, higher-level divisions of the FN may lead to the incomplete blockage of the FN. Thus, it is vital that the clinical experience and anatomical knowledge of both the anesthetist and the surgeon are adequate with regard to the origin and variations of the FN (Bösenberg *et al*., 2002). In this study, it was aimed to determine a simple method using bone landmarks to make FN blocks based on anatomical dissections in younger age groups.

MATERIAL AND METHOD

The present study was approved by the local ethics committee (decision no: 2015/189), and all the study procedures were conducted in accordance with the requirements of the Declaration of Helsinki. The study was performed using the fetal cadaver collection held in the Necmettin Erbakan University, Meram Medical Faculty Anatomy Dissection Laboratory.

The study involved 60 lower limbs of 30 aborted fetal cadavers (17 males and 13 females; ranging in age from 9–40 gestational weeks) that had no external pathologies or abnormalities. The fetuses had been fixed in 10 % formalin solution via the immersion method so that their long-term usability was ensured. In accordance with the age determination method suggested by Hensinger (1992), the ages of the fetuses (in weeks) were determined on the basis of their crown–rump length (CRL). Microdissection equipment, 0.01 mm precision digital caliper (hardened stainless steel), and a microsurgical microscope (Kaps SOM 62) were used in this study.

First, the lower abdominal regions on both sides and the ventral sides of the thigh were dissected up to the middle medial limit of the adductor canal in all the fetal cadavers. The abdominal organs were then removed. Next, the lateral side of the psoas major muscle was opened up, and the exit point of the FN was identified. The measurements were examined in two regards, namely the level of the FN and the relationship of the FN with the surrounding structures.

1. Level of the FN: The FN levels were divided into three groups, that is, in the proximal of the inguinal ligament (IL) (high-level division), on the level of the IL (mid-level division), and in the distal of the IL (lower-level division) (Fig. 1).

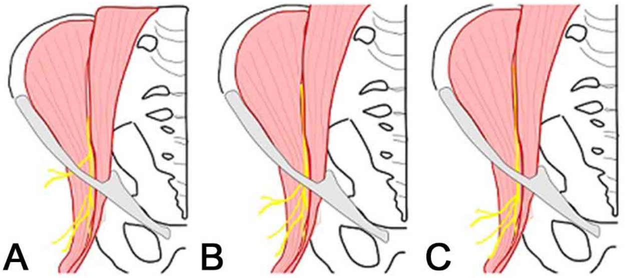

Fig. 1. Classification of femoral nerve according to division level (A: high level division, B: Mid-level division, C: Lower level division).

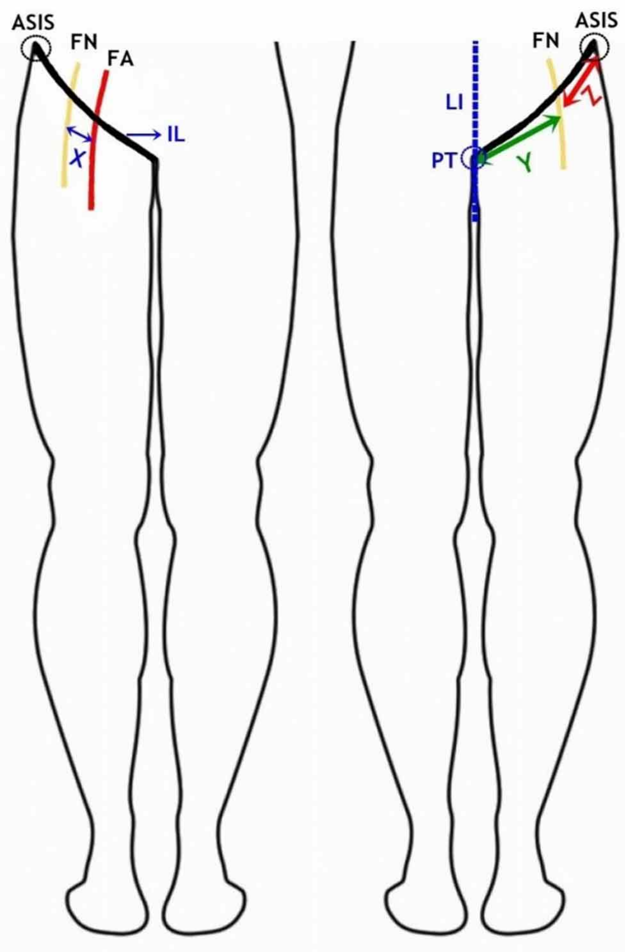

Fig. 2. The schematic view of safe sites determined for femoral nerve blockade in fetal cadavers according to gestational age (ASIS: Anterior superior iliac spine, FN: femoral nerve, FA: Femoral artery, PT: Pubic tubercule, LI: Linea intermedia, IL: Inguinal ligament, X: The distance between FN and FA, Y: The distance between FN and PT, Z: The distance between FN and ASIS).

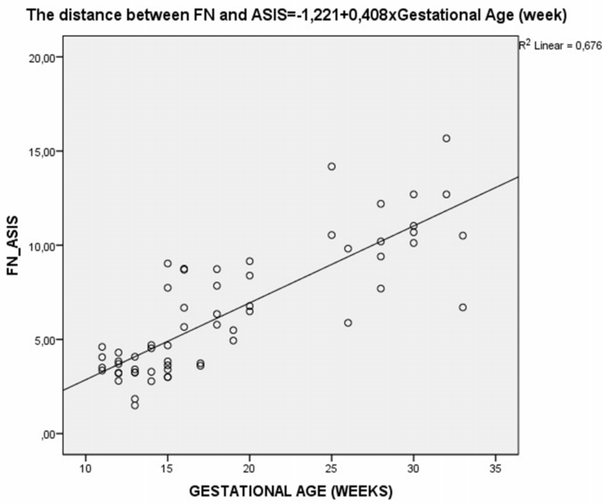

Fig. 3. Regression line between the distances femoral nerve-anterior iliac spine and gestational age.

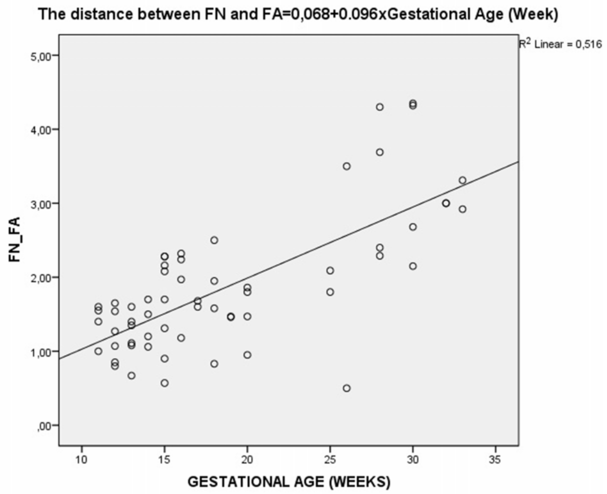

Fig. 4. Regression line between the distances femoral nerve-femoral artery and gestational age.

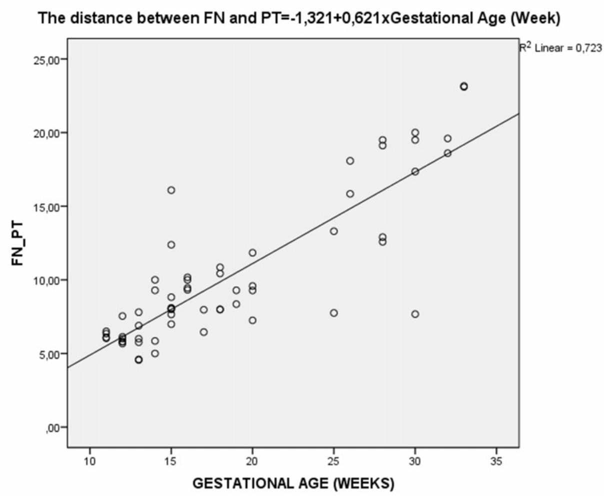

Fig. 5. Regression line between the distances femoral nerve-pubic tubercule and gestational age.

2. The FN's relationship with the surrounding structures (Gustafson *et al*., 2009; Abe *et al*., 2014; Pateliya *et al*., 2015) (Fig. 2):

a. Right/left distance from the FN to the anterior superior iliac spine (ASIS)(RFN-ASIS/LFN-ASIS): The distance between the point at which the FN originates underneath the IL and the ASIS.
b. Right/left distance from the FN to the pubic tubercule (PT) (RFN-PT/LFN-PT): The distance between the point at which the FN enters underneath the IL and the PT.
c. Right/left distance from the FN to the FA (RFN-FA/ LFN-FA): The distance between the FN and the FA at the femoral trigone.

The obtained data were evaluated using SPSS 21.0 (Statistical Package for Social Sciences). The data were analyzed using both descriptive (mean value, standard deviation, maximum and minimum values, percentages) and quantitative (one-way ANOVA, Pearson correlation, least squares regression) statistical methods. The results were evaluated statistically on the basis of a 95 % confidence interval and the differences were considered to be significant if $p<0.05$. The least squares regression method was used for the reference ranges (Figs. 3 to 5).

RESULTS

For the right and left sides, all the parameters showed increases with age (Table I). A significant relationship was found between all the parameters of the fetal cadavers ($p\leq0.01$) (Table II). When the measurements of the FN and the FN's relationship with the surrounding structures were statistically analyzed, it was determined that there was strong correlation among all the parameters ($p<0.01$). Sex was not found to be significantly related to the other parameters ($p<0.05$) (Table II).

In the present study, the distances from the FN to the ASIS, the FN to the PT, and the FN to the FA were measured separately for each of the three trimesters. The mean distances between the FN and the ASIS were found to be 3.46±0.84 mm, 6.54±2.71 mm, and 10.38±2.56 mm during the first, second, and third trimesters, respectively. Similarly, the mean distances between the FN and the PT were found to be 6.38 ± 1.38 mm, 9.36±2.16 mm, and 17.64±4.21 mm during the first, second, and third trimesters, respectively, while the distances between the FN and the FA were 1.27± 0.31 mm, 1.69± 0.51 mm, and 3.03± 1.04 mm during the first, second, and third trimesters, respectively (Table I). The separation of the FN into the anterior and posterior divisions after exiting the lateral side of the psoas major muscle was determined in cases in the proximal of the IL (high-level division), on the level of the IL (mid-level division), and in the distal of the IL (lower-level division) (Fig. 1). Among all the fetal cadavers, high-level division was observed in six limbs (10 %), mid-level division in 33 limbs (55 %), and lower-level division in 21 limbs (35 %). The distance between the high-level division type and the IL was found to be 4.91 ± 3.73 mm, while the distance between the lower-level division type and the IL was 3.32 ± 1.69 mm.

The reference ranges for the distances between the FN and the ASIS, the FN and the PT, and the FN and the FA were determined using the least squares regression method as follows:

Formula 1: The distance between the FN and the ASIS =-1.221+0.408xGestational Age (weeks)
Formula 2: The distance between the FN and the PT =-1.321+0.621xGestational Age (weeks)
Formula 3: The distance between the FN and the FA =0.068+0.096xGestational Age (weeks)

Table I. Minimum, maximum, meanvalues, standart deviations and p values of paramaters according to trimesters (mm, p<0.005).

Trimester	Parameters	N	Minimum	Maximum	Mean±SD	P value
1. trimester	FN-ASIS	20	1.50	4.70	3.46±0.84	0.000
	FN-PT	20	4.55	10.00	6.38±1.38	
	FN-FA	20	0.67	1.70	1.27±0.31	
2. trimester	FN-ASIS	26	3.00	14.18	6.54±2.71	
	FN-PT	26	6.45	16.09	9.36±2.16	
	FN-FA	26	0.57	2.50	1.69±0.51	
3.trimester	FN-ASIS	14	5.88	15.67	10.38±2.56	
	FN-PT	14	7.67	23.16	17.64±4.21	
	FN-FA	14	0.50	4.35	3.03±1.04	

FN: femoral nerve, ASIS: anterior superior iliac spine, PT: Pubic tubercule, FA: femoral artey.

Table II. The correlation between morphometric parameters related FN, sex and gestational age.

Parameters		FN-FA	FN-PT	FN- ASIS	GA	SEX
SEX	r	0.155	0.114	0.155	0.049	1
	p	0.237	0.385	0.238	0.712	
GA	r	0.718**	0.850**	0.822**	1	
	p	0.000	0.000	0.000		
FN-ASIS	r	0.581**	0.737**	1		
	p	0. 000	0.000			
FN-PT	r	0.682**	1			
	p	0.000				
FN-FA	r	1				
	p					

**Correlation is significant at the 0.01 level (2-tailed). FN: femoral nerve, ASIS: anterior superior iliac spine, PT: Pubic tubercule, FA: femoral artey, GA: Gestational age.

DISCUSSION

In this study, formulas based on the FN were produced, taking into account the nerve development that began at a prenatal age and continued during the postnatal period. Working with fetuses of different gestational ages during this process closed a significant gap in terms of monitoring nerve development. In addition, it was observed that there was no standard FN branching during the different stages of development. When the percentage of mid-level division found to meet the standard was 55 %, the percentage of lower-level division was 35 % and the percentage of high-level division was 10 %.

The distance between the FA and the FN can be determined by means of morphological measurement methods in cadavers and via ultrasound or magnetic resonance imaging (MRI) in healthy individuals. Muhly & Orebaugh (2011) performed an ultrasonographical evaluation of the relationship between the FA and the FN in 25 healthy volunteers and found the mean distance between the FA and the FN to be 11.1±2.9 mm. In an MRI study involving four healthy volunteers, the mean distance between the FA and the FN at the level of the IL was found to be 7.5 mm (range: 5–9 mm) (Mehmood *et al*., 2010).

The mean distance between the FA and the FN at the level of the IL was found to be 12.0 ± 0.4 mm in the study conducted by Orebaugh (2006). In their topographic study involving 11 fetuses, Abe *et al*. stated that the distance between the FN and the FA increased with gestational age, although they did not report any values. The distance between the FN and the FA was also found to increase with gestational age in the present study. However, unlike the study by Abe *et al*., morphometric data are included in this study. In the present study, the mean distance between the two structures was found to be 1.27±0.31 mm, 1.69±0.51 mm, and 3.03±1.04 mm during the first, second, and third trimesters, respectively. These measurements show how variable such measurements can be in infants and younger age groups.

Clinical studies have described how FN blocks can be performed 0.5–1 cm or 1–2 cm lateral of the FA under the IL in adults, although no standardization has been suggested for pediatric groups (Oberndorfer *et al*., 2007; Farid *et al*., 2010). This indicates that the application of the landmark technique used in adults and adolescents may result in arterial or nerve injuries in younger age groups. In terms of the blockage of the entire anterior of the thigh, the FN and the lateral femoral cutaneous nerve are involved in the block. In this case, a standard landmark-based blocking technique is applied. Yet, in the three-in-one technique, where the FN, the lateral femoral cutaneous nerve, and the obturator nerve are used together, the morphometric data related to the ASIS and the PT are of considerable importance in relation to the FN block (Byun & Pather, 2019). Additionally, the localization of the FN is important in surgical operations in which the IL is used as the starting point for the dissection. Therefore, it is clinically important to determine the distance from the point at which the FN enters beneath the IL to the ASIS and the PT. Cadaver studies have revealed that the FN enters beneath the IL and closer to the ASIS (Gustafson *et al*.; Pateliya *et al*.). The results we obtained in fetal cadavers, similar to the results obtained in prior studies, showed that the FN enters beneath the IL and closer to the ASIS. In addition, the measurements were found to be shorter in fetal cadavers than in adult cadavers.

The anatomic course and branching of the FN are important in relation to blockage surgeries. An FN blocks only performed on the main body of the femur under the IL. High-level divisions of the FN lead to incomplete nerve blockage (Astik & Dave). Anatomical variations and different branching patterns are not rare in the FN. Astik & Dave found anatomical variations to occur in the lumbar plexus in as high as 25 % of cases in cadaveric studies, while Anloague *et al*. (2009) reported variations in 35 % of cadaveric dissections. Researchers who have performed division-level measurements independently of muscle variations have also reported high-level divisions (Gustafson *et al*.; Pateliya *et al*.; Sripriya & Sivashanmugam, 2018). In a 60-year-old male cadaver, Saha & Pakhiddey (2013) reported that the dissection of the FN was bilaterally diverged from the lateral margin of the psoas major muscle to 4.10 cm above the IL (Saha & Pakhiddey). This distance was reported to be 3.2 cm and 3.5 cm above the IL by Das & Vasudeva (2007) and Jiji *et al*., respectively. Astik & Dave reported high-level divisions in two cadavers. The FN was divided 4.0 cm proximal to the IL on the right side of the male cadaver and 3.8 cm proximal to the left IL in the female cadaver (Astik & Dave; Jiji *et al*.; Saha & Pakhiddey). In the present study, it was determined that the division was high level in six limbs, middle level in 33 limbs, and lower level in 21 limbs. The distances between the division point and the IL were 4.91±3.73 mm and 3.32±1.69 mm in the high and lower-level division types, respectively. In addition, high and mid-level divisions were found to occur in very high percentages of cases (10 % in high level, 55 % in middle level) in this study. The use of FN blocks for postoperative pain control following orthopedic and surgical operations in the hip, the proximal part of the femur, and the lateral part of the thigh, including biopsy and skin graft collection, may prove ineffective in the event of high-level divisions and so negatively affect the success of such surgeries. Additionally, the findings of this study indicate that the use of ultrasound should be compulsory in infants and young children due to the differences in the divisional levels seen in fetal cadavers, which is likely related to development.

The use of a standard technique based on superficial anatomical structures and landmarks for femoral blocks among pediatric populations of different ages increases the success of the blockade. Accordingly, this study sought to achieve standardization by creating regression equations dependent on gestational age. In addition, in the present study, the percentage values of the course variations that could decrease the effectiveness of the blockage were determined. It is thought that the data obtained from the study will increase the success rate of FN blockade in younger age groups.

AUTHOR CONTRIBUTONS

All of authors contributed to the concept or design of the work, data analysis and interpretation of the data, drafting the work or revising it critically for important intellectual content and final approval of the version to be published.

CIHAN, E.; BUYUKMUMCU, M.; AYDIN KABAKCI, A. D.; AKIN, D. & GUNGORER, S. Una guía para el bloqueo del nervio femoral con fórmulas relacionadas con la edad obtenidas a partir de las distancias entre el nervio femoral y los puntos de referencia anatómicos superficiales en cadáveres fetales. *Int. J. Morphol., 40(1)*:62-67, 2022.

RESUMEN: El nervio femoral (NF) se utiliza para el bloqueo nervioso en muchas cirugías y proporciona analgesia posoperatoria eficaz en la población pediátrica. Sin embargo, aunque existen suficientes mapas anatómicos y signos de bloqueo del NF en los individuos adultos, no hay suficiente información para el grupo pediátrico. Se intentó determinar una área exacta para el bloqueo del NF junto con estructuras óseas para realizar un bloqueo efectivo. El estudio se realizó en 60 miembros inferiores. Se identificó el punto de salida del NF. Las mediciones se realizaron en dos puntos, nivel del NF y la relación de éste con las estructuras circundantes. Para los lados derecho e izquierdo, todos los parámetros mostraron incrementos con la edad. Se encontró una relación significativa entre todos los parámetros de los cadáveres fetales (p<0,01). Se determinó que existía una fuerte correlación entre todos los parámetros relacionados con el NF y las estructuras óseas circundantes (p <0,01). No se encontró que el sexo se relacionara significativamente con los otros parámetros (p<0,05 Entre todos los cadáveres fetales se observó un alto nivel de división en seis miembros (10 %), una división de nivel medio en 33 miembros (55 %) y división de nivel inferior en 21 miembros (35 %). Las ecuaciones de regresión basadas en la edad gestacional del estudio mostraron que el sitio de bloqueo se podría realizar eficazmente con la ayuda de estructuras óseas palpables desde el exterior sin necesidad de asistencia técnica.

PALABRAS CLAVE: Nervio femoral; Anestesia regional; Guía; Infantil; Variación; Microdisección.

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