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Original Research Article

Analytical and morphometric study of nutrient foramina of femur and its clinical implications

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ABSTRACT

Background: The femur is supplied princially by the diaphyseal nutrient artery which enters the bone throught the nutrient foramen. This supply is essential during the growing period, the early phases of ossification, and in different surgical procedures. The aim of present study was to examine the morphology and topography of the femur nutrient foramen to provide detalied data on such features.
Methods: This was a cross-sectional-descriptive study in which we observed 50 femurs. We analysed the number and location of nutrient foramina, the length of the bone, the position of the nutrient foramen regarding to values of FI, correlation between number of nutrient foramen and length of femur, correlation between position of nutrient foramen and side of extremity to which femur belongs.
Results: The double foramina were common in right (57.1%) and left (42.1%) femur, mostly located in medial lip of aspera line in right (64.3%) and on the lateral lip in left femur (68.4%), with statistically significant correlation, χ = 4.85; p = 0.03, $p < 0.05$. The foramina in left (89.5%) and right (96.4%) femur were commonly observed at their middle third, with no statistically significant correlation between position of foramen accordingly to Foraminal Index value and side of extremity on which femur belongs (p=0.56; $p > 0.05$). There is positive correlation between length of right and left femur and number of foramina.
Conclusions: The study provides data of the nutrient foramina on femur, which is helpful for clinicians to help preserve bone vascularization during surgery.

Keywords: Femur, Nutrient foramen, Topography, Vascularization

INTRODUCTION

Detailed knowledge of anatomy is critical to any surgical intervention. Knowing the location of different structures in the body is a prerequisite for adequate diagnosis and choice of surgical method. Unfortunately, individual variations in anatomic structure often pose a risk for diagnosis and treatment.[1] There are current studies that show that more than 10% of clinical deaths occur as a result of ignoring the existence of anatomical variations.[2] Although most human anatomical variations are recorded and cataloged, their combinations are still of interest.

Long bones have three different vascular systems that are interconnected. Those are the metaphysical complex, the nutritive system and the periosteal capillary system. The nutritional system is the largest, and supplies blood to the bone marrow and the inner two thirds of the bone marrow.[3] Nutritional arteries are the main source of long bone blood and their special importance is during the active period of embryo and fetal growth, as well as during the early ossification period.[4] Each long bone has its own nutrient artery, and some of them even more. They are usually collateral blood vessels of extremity arteries. One or two major nutrient arteries enter the dyaphisis of long bones through one or two nutritional foramina (NF) leading into the nutrient canal.

For some bone pathological processes such as development anomalies, severe healing of fractures or acute osteomyelitis is considered to be closely related to changes in bone vascularization.[5] The regenerative process of all bone structures increases with increased blood flow.[6] The degree of damage to the vascular bone network affects the speed and shape of the calus formation.[7] When blood supply is not established, it may result in non-union or delayed union of fracture and prolongate of healing time.[8] Hence, by knowing the anatomy of NF, the surgeon can prevent the damage of nutrient arteries and post-operative complications. Preservation of vascularization is also very important during bone transplantation, due to the fact that after taking graft from the bone, enough vascularization needs to be preserved for bone to continue its normal function. On the other hand, taken bone graft also need proper vascularization in order to survive after transplanation.[9,10]

The femur is the longest bone in human body. It is typical long and principal load-bearing bone located in thigh. The femoral dyaphisis fracture is a frequent occurrence in the action of force on it, such as injury to traffic accidents, dropping from high heights, sport injuries or gunshot injuries. The success of treating fracture depends on the degree of vascularization. Traumatic or iatrogenic injury of the nutient artery will result in delayed healing. Knowing the frequency of NF will help orthopedists avoid vascular injuries, estimate the prognosis of the operation, and gain better outcomes during transplantation and treatment of fractures.[11] Precise knowledge of NF is also useful for anthropologist during interpretation of height from a fragment of bone in medico- legal cases.[12]

Investigations on the vascular anatomy of long bones were in the past confined mostly to animals. A few authors have studied nutrient foramina in human long bones including the femur. Considering all the above facts, the aim of present study is to determine the number, position and correlation these parameters to the total length of the femur, and its most important clinical application of these variations.

METHODS

The material of the present study consists of 50 (29 right and 21 left) adult human cleaned and dried femurs. They were obtained from the osteology collection held in the Department of Anatomy, Faculty of Medicine, University of Sarajevo. All selected bones were normal with no appearance of pathological changed. Bones which had gross pathological deformities were excluded from the study. Age and sex of the person from whom the bone originate were not known. We observed NF macroscopically only on dyaphisis of each bone with help of a hand magnifier with 6x magnification. The NF were indentified by their elevated margins and a well marked distinct groove proximal to them.

The following data were studied on the dyaphyseal NF of each bone:

Total number of NF

For each bone we recorded total number of macroscopic observed foramina on the diaphysis. Through each foramina we pulled a fine wire to verify the existence of NF.

Total length of the bone

Determination of the total length of the bone was done individually for each bone, with help of osteometric board, as the distance between the most proximal point of the femoral head and the most prominent position on the median condyle.

Position of NF regarding the side of the diaphysis of bones

For femur the NF position was determined with respect to the relationship to the lateral or medial lip of aspera line at the posterior aspect of the femur.

Foraminal Index (FI) and the position of the nutritional foramen due to the value of FI

The exact position of each NF is determined by calculating the Foraminal Index (FI), using the following formula:

$FI = (DNF/TL) \times 100$;

Where, (DNF = distance between the proximal end of the bone and the NF; TL = total length of the bones).

In those bones that had two NF, bigger one was taken to calculate the FI. Diaphysis of each bone is divided into three equal parts, zones: zone I (proximal 1/3), zone II (middle 1/3) and zone III (distal 1/3). NF were divided into three groups regarding the value of FI:

- Type 1: FI value to 33.33, NF is in the proximal third of the dyaphisis.
- Type 2: FI value from 33.33 to 66.66, NF is in the middle third of the dyaphisis.
- Tip 3: FI value through 66.66, NF is in the distal third of the dyaphisis.

The observations were meticulosly recorded and tabulated. The morphometric values were subjected to statistical analysis. Categorical data were expressed in frequencies and the relevant percentages. The significance of differences in frequencies within the relevant subgroup was tested by Chi-square test or Fisher's exact test. The existence of associations between categorical variables was tested by Chi-square test. To estimate the normal distribution of continuous variables we used the Kolmogorov-Smirnov and Shapiro-Wilk test, depending on the sample size.

For independent continuous variables that followed a normal distribution the mean and standard deviation (SD) was determined. The significance of differences for continuous independent variables that followed a normal distribution was tested by Student t-test. Value of $p < 0.05$ was considered statistically significant. The obtained data were statistically analysed using SPSS version 17.

RESULTS

The average length of femors was 44.34±2.5cm (min. 38.0cm; max. 49.0cm). The right femur had an average length of 44.30±2.4cm, while the left had an average length of 44.38±2.7cm. The difference between the average length of the femur of the right and left extremities was not statistically significant (p=0.915, p>0.05) (Table 1).

Table 1: Length of femur.

	Femur of the right extremity (n=29)		Femur of the left extremity (n=21)	
Length (cm)	44.30±2.4		44.38±2.7	
	Min.	Max.	Min.	Max.
	38.0	48.5	39.2	49.0

Analysing the presence of NF we found that 47 (94.0%) femurs had present NF, 28 (96.6%) right and 19 (90.5%) left femurs. 6% of observed femurs did not have NF. One NF was observed on 9 (32.1%) right and 10 (52.6%) left femurs. Two NF were present on 16 (57.1%) right and 8 (42.1%) left femurs, and three NF were observed on 3 (10.7%) right and 1 (5.3%) left femur (Table 2).

Table 2: The number of NF on femur.

Number of NF (n)	Femur of the right extremity		Femur of the left extremity	
	n	%	n	%
1	9	32.1	10	52.6
2	16	57.1	8	42.1
3	3	10.7	1	5.3
Total	28	100.0	19	100.0

Out of total number observed femurs, 24 (51.1%) of them had NF located on medial lip of aspera line [18 (64.3%) right and 6 (31.6%) left], and 23 (48.9%) of femurs had NF located on lateral lip of aspera line [10 (35.7%) right and 13 (68.4%) left] (Table 3).

Table 3: Position of NF on femur regarding parts of bone dyaphisis.

Bone	Part of linea aspera	Number of NF			
		Right femur		Left femur	
		n	%	n	%
Femur	Medial lip	18	64.3	6	31.6
	Lateral lip	10	35.7	13	68.4

The frequency of NF on the medial lip was 75.0% for right and 25.0% for left femurs. The frequency of NF on the lateral lip was 43.5% for right and 56.5% for left femurs. Analyzing the correlation between the extremities and positions in relation to the defined parts of aspera line on femur, we determined the existence of statistically significant dependence (χ = 4.85; p = 0.03, p <0.05) (Table 4).

Table 4: Correlation between position of NF and parts of aspera line on femur.

Parts of aspera line	Femur of right extremity		Femur of left extremity		Total	
	n	%	n	%	n	%
Medial lip	18	75.0	6	25.0	24	51.1
Lateral lip	10	43.5	13	56.5	23	48.9
Total	28	-	19	-	47	100.0

The NF were localized in dyaphiseal middle third on 27 (96.4%) of right and 17 (89.5%) of left femurs, and on proximal third NF were present on 1 (3.6%) right and 2 (10.5%) left femurs (Table 5).

Table 5: Position of NF based on value of foraminal index.

Position of NF	Femur of right extremity		Femur of left extremity	
	n	%	n	%
Proximal 1/3 of the dyaphisis	1	3.6	2	10.5
Middle 1/3 of the dyaphisis	27	96.4	17	89.5
Distal 1/3 of the dyaphisis	0	0.0	0	0.0
Total	28	100.0	19	100

The frequency of the NF in the proximal third on right femur, based on the FI value was 33.3%, and 66.7% for left femur. The frequency of the NF in the middle third of the right femur was 61.4%, and 38.6% for left femur (Table 6).

Analyzing the correlation between the position of NF based on the FI value and the number of NF on the right and left femurs extremities, we did not establish the existence of statistically significant dependence (p = 0.56, p>0.05) (Table 6).

We established a positive correlations between the length of the right and left femur and the number of NF. The established correlations were not statistically significant (Table 7).

Table 6: Correlation of NF position based on FI value and a number of NF on right and left femur.

Position of NF	Femur of the right extremity		Femur of the left extremity		Total	
	n	%	n	%	n	%
Proximal 1/3 of the dyaphisis	1	33.3	2	66.7	3	6.4
Middle 1/3 of the dyaphisis	27	61.4	17	38.6	44	93.6
Distal 1/3 of the dyaphisis	0	0.0	0	0.0	0	0.0
Total	28	-	19	-	47	100.0

Table 7: Correlation between length of femur and number of NF.

Variable	Number of NF
Length of the femur (right extremity)	r = 0.219
Length of the femur (left extremity)	r = 0.260

r-correlation coefficient, *-p<0.05

DISCUSSION

The external opening of the nutrient canal, usually referred to as the nutrient foramen (NF), has particular position for each bone. The diaphysis of large bones, such as femur, is irrigated by one or more nutrient arteries that pass by cortex, entering medular cavity in which is divided into ascending and descending branches. It is generally agreed that these nutrient arteries are derived from those that took part in the initial invasion of the ossifying cartilage.[13,14]

The mean total length obtained in the present study is 44.34±2.5cm, which is almost similar to the results obtained by the Kirschner et al, 40.8cm, Kizilkanat et al, 42.58cm, Nagel et al, 40.1cm, Kirschner et al, 40.8cm.[9,10,15]

In the present study we found that most of the right femur had two NF (57.1%), as well as most of left femurs (42.1%). Kumar reported one NF in 32% of observed femurs and two NF in 68%.[16] These results are similar to those of Kizilikanat (60% with two NF) and Forriol Campos (75% with two NF).[10,17] Gopalakrishna and Rathna reported one NF in 59.49%, and two NF in 40.51% of femurs.[11] The observation that about 40% of the bones have two NF is similar to that reported by Mysorekar, Gumusburun, Prashanth, Sendemir and Çimen.[18-21] Unlike in our study, they did not separate the bones on the sides of the limbs they belong to.

In present study 6% of femurs did not have NF. Previous studies reported absent NF in 1.9% and 4.6% by Gumusburun et al, and Prashant et al, respectively.[19,20] In the absence of NF, the shaft of the femur recives irrigation from the periosteal vessels.[22]

Differences in the frequency of NF in different populations may be related to genetic constitution or anthropometric differences among populations. These factors are believed to determine the number and location of the appearance of NF on the dyaphisis.[20]

In our study, most of NF were located mainly around linea aspera and along a narrow strip on either side of it. We determined that in right femurs NF were mostly been found on medial lip of linea aspera (64.3%), and on left femur on lateral lip of linea aspera (68.4%). There was statistically significant correlation between position of NF on the parts of linea aspera and between the extremities to which the femur belongs. Frequency of occurrence of NF on medial lip in right femur was 75%, and on lateral lip in left femur was 56.5%. These results were similar to those of Sendemir and Çimen, Lutken, Laing, Kumar, who stated that most of the NF were found on parts of linea aspera.[21,23-25]

The least occurance of NF on anterior and lateral aspect of femur dyaphisis make these two sites the safeist for orthopedic manipulations. At these sites, injury to the NF is unlikely to happen.

In the present study, NF were mostly located in middle third of the dyaphisis (96.4% of right and 89.5% of left femurs). There was not significant correlation between nnumber of NF and position of NF according to the values of FI.

These results are in agrrement with Gopalakrishna et al. (82.28%), Kumar (52%) and Bhatnagar et al. (83.5%).[11,25,26]

These results show that the femur's NF is closer to the hip joints than the knee. Proportionally, the proximal part of the femoral diaphysis has multiple muscle attachments in comparing to the distal part.[11]

In the results of our study there is a positive correlation between the length of the right nad left femur and the number of NF, but the established correlations were not statistically significant. In addition, studies with larger sample size could be needed to determine for sure these correlations.

This study has some limitations. These include age and sex differences which were not considered as we were not able to estimate the age and gender of the bones studied. These differences might impact the results, since in older age sone of NF might get ossified, and NF might differ in males and females. A futher cadaver-based study is therefore advocated in which the origin of the NF and the sex of femurs can be determined.

CONCLUSION

The present study provides additional information on the femur nutrient foramina topography. It also provide important information to the clinical significance of nutrient foramina. Exact location and distribution of the nutrient foramina in femur diaphysis is important to avoid damage to the nutrient vessels during surgical procedures, and to improve outcome of microvascular bone graft and ensuring adequate endo-periosteal flow.

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