Original Article

Determination of the Positions of the Nutrient Foraminae in the Human Adult Lower Limb Long Bones

Positions of the Nutrient Foraminae in Lower Limb Long Bones

Ejaz Afzal[1], Fatima Sherin[5], Abdul Haq Wazir[2], Zahid Irfan Marwat[3], Muhammad Junaid Khan[2] and Anwar Khan Wazir[4]

ABSTRACT

Objective: To determine the positions of the nutrient foraminae (NF) in the human adult lower limb long bones.
Study Design: Descriptive study
Place and Duration of Study: This study was conducted at the Forensic Medicine and Anatomy Departments of Nowshera Medical College, Nowshera and Ayub Medical Colleges, Abbottabad, K.P.K. from March to July 2018.
Materials and Methods: Thisstudy was done on 90long bones of the lower limb. After inclusion and exclusion criteria, total number, position,and direction of all of the foraminae were observed macroscopically. The foraminal index was calculated by Hughes H formulae and divided into three types.
Results: In the case of femora, (79.61%) of NF were located along the middle third of the diaphysis. While rest was in Proximal 3rd, the distal 3rd had no foraminae. In cases of tibiae, 83.3% were located on the Proximal 3rd. The rest of NF were located in the middle 3rd. The distal3rd had no foraminae. In cases of fibulae, most of the NFwere located on the middle 3rd (97.2%). This distal 3rd of the bones had rest of the foraminae (2.8%).
Conclusion: Our study confirmed the previous reports regarding the number and position of the NF in the human long bones of the lower limbs. The variation in NF is also very important in forensic radiology, anthropometry, and differentiation of human and non-human bones.
Key Words: Femora, Tibiae, Fibulae, Nutrient Foraminae, Diaphysis.

Citation of article: Afzal E, Sherin F, Wazir AH, Marwat ZI, Khan MJ, Wazir AK. Determination of the Positions of the Nutrient Foraminae in the Human Adult Lower Limb Long Bones. Med Forum 2019;30(3):66-70.

INTRODUCTION

Skeleton of the human body consists of two hundred and thirteen bones, not including the sesamoid bones[1]. The axial system consists of seventy-four bones; the appendicular system consists of hundred and twenty-six bones, ear bones which are six in number. During life each bone undergoes modeling and also helps to remove the old bone, which is damaged is replaced by the new and the strength of bone is preserved by producing mechanically stronger bone[2].

Four categories of bones are present; long bones, short bones, flat bones, and irregular bones.

1. Department of Anatomy / Forensic Medicine[2] / Biochemistry[3] / Physiology[4], Nowshera Medical College, Nowshera.
5. Department of Anatomy, Ayub Medical College, Abbottabad.

Correspondence: Dr. Zahid Irfan Marwat, Associate Professor, Department of Biochemistry, Nowshera Medical College, Nowshera, K.P.K
Contact No: 0300-9112880
Email: drzahidirfan@gmail.com

Received: November, 2018
Accepted: February, 2019
Printed: March, 2019

The lower limb bones are long bones; femur, tibia, fibula, metatarsals, and phalanges. Their formation is both by endochondral and membranous ossification, while flat bones develop by membranous bone formation[3].

Skeleton provides structural support to the body, acts as levers for the muscles by permitting movement, protects internal organs, maintain the mineral and acid-base balance in the body. The bones are also a reservoir for the cytokines and the factors that help in the growth. Blood cells are also produced by the marrow of shaft (diaphysis) of the long bone[4]. Primarily dense cortical bone makes the diaphysis while trabecular bone forms other parts, covered by a thin shell of dense cortical bone[5].

The blood circulation is necessary for the maintenance of bone vitality, osteogenesis, growth and repair after injuries[6]. The long bones blood supply is usually by three different vessels:the nutrient arteries and the periosteal vessels, epiphyseal-metaphyseal vessels at the ends of bones, one or more arteries that enter the diaphysis [7].The six groups of arteries of long bones are: proximal epiphyseal, proximal metaphyseal, distal metaphyseal, diaphyseal nutrient, periosteal arteries anddistal epiphyseal. The adjacent groups of arteries anastomose freely with each other and help in compensation[7]. A nutrient artery does 10% blood supply to the diaphyseal cortex and 90% to marrow.

Itdivides into ascending and descending branches after entering the diaphysis. The lateral branches radially extend outwards from the endosteal surface towards the diaphyseal cortex, supplying the Haversian canals and thus supplying the cortex. The terminal branches of the main ascending and descending branches of the nutrient artery supply ends of the bones.

All the bones possess either small or large foramina, and these serve asan entrance of the blood vessels. These foramina are called as the "Nutrient Foramina." They are larger, particularly in the long bone shafts where these lead into a nutrient canal,and then in the medullary cavity[9].The nutrient canals are found in both the long and the irregular bones.Nutrient arteries and veins pass through these canals. In long bones, these foramina are found in the shaft while in irregular bones these are found in other locations.

Variation in direction of nutirent foramina is well established. It is determined by the osteogenitically activeend of the bone. The nutrient vessels move away from the growing end of the bone. Besides, radiological, anthropological and anatomical, it is also important to know about the position, direction and foraminal index for surgeons and medico-legal cases[10,11.12]. For forensic anthropological cases, NF are used to determine gender and differentiate between human and non-human bones[13,14]. Even though, some novel forensic techniques like virtposy and CT imaging has beensuggested for measuring the circumference, area of the entrance, length and angle of the canal, of the foramen[15, 16].

Keeping its anatomical and forensic importance in view, it is a very subtle and vital to know variation of nutrient foramen in our setup, therefore, we attempt to determine the positions of the nutrient foraminae in the human adult lower limb long bones.

MATERIALS AND METHODS

This descriptive study, conducted on 90 (30 femora, 30 tibiae, 30 fibulae) lower limb long bones obtained from Bone collections and osteology sections of Forensic/AnatomyDepartments of Nowshera Medical College, Nowshera, and Ayub Medical College, Abbottabad, K.P. Pakistan after taking ethical approval from the said institutions. These bones were cleaned, dried and evaluated by the authors of respective departments and, then placed back into same collection/section.The age, race and sex of the bones were not determined. The NFwere included which were present on the diaphysis of the bones. All fractured bones and thosewith gross pathological deformities or NF not well-defined or present at the ends of bones orforamina smaller than a size 24 hypodermic needle were excluded. A magnifying lens(12X) was used in the macroscopic examination of the bones. Direction and Obliquity was confirmed with a stiff wire.The NFwere observed as related margins with a proximal groove. The position of the foramina in relation to specific borders on surfaces of the diaphysis was analyzed. Measurements were taken using an INOX sliding caliper.The foraminal index (FI) was calculated by applying the Hughes H formula.Total length of bones was taken as the distance between:

proximal part of head of femur and distal aspect of medial condyle**--Femur**

proximal margin of medial condyle and tip of medial malleolus**--Tibia**

apex of head of fibula and tip of lateral malleolus**--Fibula**

According to FI the subdivisions of position of foramina, it was divided into following three types:

Type 1: Up to 33.33, in proximal third of bone.

Type 2: From 33.33 up to 66.66, in the middle third of bone.

Type 3: Above 66.66, in distal third of bone.

The statistical analysis was carried out using SPSS-21. The descriptive statistical analysis was performed through frequency tables and the calculation of central tendency and variability measures

RESULTS

In femur, the NF were present along the middle third. The foramen index ranged between 29.71 and 62.50% of the bone length (Table-1).

Table No.1: The range, mean ±, standard deviation (SD) of foraminal indices of the Femur.

Position	Side	Range	Mean ± SD
Between the two lips of liean aspera	R L	36.06-62.50 37.06-38.30	46.00±11.55 37.63±00.75
Medial lip of liea aspera	R L	37.26-60.28 43.8-59.10	52.54±9.48 54.93±7.27
Lateral lip of linea aspera	R L	35.32-61.12 35.80-51.50	46.25±10.16 41.70±8.55
Posterio medial surface	R L	45.10-59.04 55.10-60.50	55.47±5.81 57.18±3.03
Medial to spiral line	R L	29.71-31.92 -	31.12±00.91 -
Gluteal Tuberosity	R L	31.70-34.20 31.80-37.25	33.07±1.26 34.06±2.87

Out of 48 NF of femur, 10 (20.8%) were in Type-1,and 38 (79.16%) were Type-2. No NFwere seen in the distal third (Type-3) (Table-2). Out of all femoral NFof femur, 10 (20.8%) were on the medial lip of the linea-aspera, & 7(14.5%) on the lateral lip of linea-aspera(Table-3).

Table No.2: According to Femoral Index, types of Position and direction of nutrient foramina in the long bones of lower limb

Bone	Position			Direc-tion
	Type-1	Type-2	Type-3	
Femur	10 (20.8%)	38 (79.16%)	-	Proximally
Tibia	25 (83.3%)	5 (16.6%)	-	Distally
Fibula	-	35 (97.2%)	1 (2.7%)	28 Distally 8 Proximally

Table No.3 Position, Number and Percentage of Nutrient Foramina observed in Femora

Position	Total number of foramina	%tage
Between the two lips of linea aspera	9	18.75%
Medial Lip of linea aspera	10	20.8%
Lateral Lip of linea aspera	7	14.5%
Posteromedial Surface	10	20.8%
Postero lateral Surface	3	6.25%
Medial to spiral line	3	6.25%
Gluteal Tuberosity	6	12.5%

Table No.4: The range, mean ± standard deviation (SD) of foraminal indices of the Tibia.

Position	Side	Range	Mean ± SD
Posterior Surface (midway between interosseous border and soleal line)	R L	27.90-31.48 27.79-34.14	29.47±1.43 31.24±2.62
Posterior Surface (close to interosseous border)	R L	28.50-32.10 26.47-35.48	30.25±1.45 30.56±3.06

The NF,in cases of tibiae were located with the foramen index ranging between 26.47 and 35.48% of the bone length (Table-4).Out of 30, 25 (83.3%) were Type-1 and 5 (16.6%) Type-2. No Type-3 NF were seen.(Table-2).All NF were present on the posterior surfaces of the tibiae, 17 (56.6%) closer to the interosseous border (Table-5)

All the NF of fibulae were present at the middle third of the bone. The foramen index ranged between 35.16 and 67.70% of the bone length (Table-6).

Out of 36 NF, 35 (97.2%) were in the middle third (Type-2) and 1 (2.7%) at the distal third (Type-3). No NF in the proximal third (Type-1) (Table-2).

Out of all the fibular NF, 26(72.2%) were at the medial crest of the posterior surface (Table-7).

Table No.5: Position, Number and Percentage of Nutrient Foramina observed in Tibiae

Position	Total number of foramina	%tage
Posterior Surface (midway between interosseous border & soleal line)	10	33.3%
Posterior Surface (close to interosseous border)	17	56.6%
Posterior Surface (close to the soleal line)	3	10%

Table No.6: The range, mean ±, standard deviation (SD) of foraminal indices of the Fibula

Position	Side	Range	Mean ± SD
Posterior Surface (on the medial crest)	R L	35.16-61.70 36.21-50.10	44.99±8.04 43.17±4.05
Posterior Surface (between medial crest and interosseous border)	R L	36.01-65.30 40.20-67.70	52.71±13.00 55.02±12.74

Table No.7: Position, Number and Percentage of Nutrient Foramina observed in Fibulae

Position	Total number of foramina	%tage
Posterior Surface (on the medial crest)	26	72.2%
Posterior Surface (between medial crest and interosseous border)	9	25%
Lateral Surface	1	2.77%

DISCUSSION

In our study, the nutrient foramina (NF) (79.61%) were located along the middle third of the femur, while the rest were located in the proximal third, while the distal third of the femur had no NF. These results fit with other studies[17,18,19,20]. Forriol Campos reported that the location in the linea-aspera is 93.4% of the bones whereas NF is closer to the hip joint[21]. In our study, 54.05% of the NFwere located along the linea-aspera. In previous studies conducted by Longia, et al., Others also showed the familiar result[17,20,22]. In our study on Tibia, 83.3% of the NF were located on the proximal third of the tibiae, and the foramen index ranged between 26.47% and 35.48% of the bone length. The distal third of the tibiae did not have any foramina. This is in accordance to some previous studies[17,18,21]. However, one study reported that the most of the tibiae had NFin the middle third with the foramen index ranging from 27%to 63% of the bone length. In our study, all the NFwere located on the posterior surface of the tibiae. The distal third of tibiae have delayed healing when the fractures of this region occur. The reason for this is the decreased blood supply in this region [19].

In our study of the fibulae, most of the NFwere located on the middle third of the bone (97.2%) and the foramen index ranged between 35.17% and 67.78% of the bone length. The distal third of the bone had (2.8%) of the rest of the NF. This isin accordance with the previous studies by[17, 18, 19]. Contrary, Guo stated that the majority of the NF were present in the proximal third of the fibulae[23].

In our study, 72.2% of the NF were present on the medial crest and 25% on the posterior surface and is supported by many other authors [17,18,19,21,24]. However, one study showed that the majority of the foramina were present on the medial surface of the fibula[20].

Collipal and McKee stated that the NF were located in the middle third of the fibulae and this segment must be used for the transplant so that the implant includes endosteal vascularization and peripheral vascularization[18, 24].

In all bones, NF were mostly located on posterior surface. As Kizil Kanat stated that the area of the bone with maximum muscle attachment was directly relatedwith the requirement of a continuous blood supply[19]. The reason for this may be that the flexor muscles are stronger and more active and need increased blood supply as compared to the extensor muscles of upper and lower limbs.

CONCLUSION

Our study confirmed the previous reports regarding the number and position of the nutrient foramina in the human long bones of the lower limbs. It also provide further information on the morphology, foraminal index, and topography of the nutrient foramina. Its variation is also very important in forensic radiology, anthropometry and differentiation of human and non-human bones. So further studies are needed to acquire such objectives.A good understanding of the characteristic morphological features of the nutrient foramina by the orthopedic surgeons and forensic specialistis recommended.

Author's Contribution:

Concept & Design of Study:	Ejaz Afzal
Drafting:	Fatima Sherin, Abdul Haq Wazir
Data Analysis:	Zahid Irfan Marwat, Muhammad Junaid Khan, Anwar Khan Wazir
Revisiting Critically:	Ejaz Afzal, Fatima Sherin
Final Approval of version:	Ejaz Afzal

Conflict of Interest: The study has no conflict of interest to declare by any author.

REFERENCES

1. Hamilton WJ. Textbook of human anatomy / edited by WJ Hamilton. London: Macmillan; 1976.
2. Olszta MJ, Cheng XG, Jee SS, KumarR, Kim Yi-Y, Kaufman MJ, ET AL. Bone structure and formation: A new perspective, Materials Science and Engineering R Reports 2007;28:58(3-5): 77-116.
3. Wibowo D. Practical human anatomy / Daniel Wibowo ; Peter Chapman, editor. Chapman PD, editor. Acacia Ridge, Qld: Australian eBook Publisher;2014.
4. Taichman RS: Blood and bone: Two tissues whose fates are intertwined to create the hematopoietic stem cell niche. Blood 2005;105:2631–2639.
5. Götzen N, Cross AR, Ifju PG, Rapoff A J. Understanding stress concentration about a nutrient foramen. J Biomech 2003;36:1511–1521.
6. Grabowski P. Physiology of bone. In Calcium and Bone Disorders in Children and Adolescents 2009;16:32-48). Karger Publishers.
7. Nilsson O, Marino R, De luca, et al. Endocrine regulation of the growth plate. Horm Res 2005;64:157-165.
8. Wang Y, Gilbert SR, Clemens TL, Oxygen sensing and osteogenesis. Skeletal Biology and Medicine, Pt B 2007; 1117: 1-11.
9. Hadjidakis DJ, Androulakis II. Bone remodeling. Annals of the New York Academy of Sciences 2006;1092(1):385-96.
10. Datta M, Saha , Chakraborty S, Biswas S, Sharma S. Analytical and morphological study of nutrient foramina of human femur. Int J Anatomy, Radiology and Surg. 2017; 6(2): 10-14.
11. Mansur DI, Manadhar P, Haque MK, Mehta DK, Duwal S, Timalsina B. A Study on Variations of Nutrient Foramen of Humerus with its Clinical Implications. Kathmandu Univ Med J 2016;53(1): 78-83.

12. Rao VS, Kothapalli J. The Diaphyseal nutrient foramina architecture - a study on the human upper and lower limb long bones. IOSR J Pharmacy and Biological Sci 2014;9(1):36-41.
13. Šlaus M, Bedić Z, Strinović D, Petrovečki V. Sex determination by discriminant function analysis of the tibia for contemporary Croats. Forensic Sci Int 2013;226:302.e1–302.e4.
14. Hauser G, De Stefano G. Epigenetic variants of the human skull. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung (Nägele u. Obermiller); 1989.
15. Johnson V, Beckett S, Márquez-Grant N. Differentiating human versus non-human bone by exploring the nutrient foramen: implications for forensic anthropology. Int J Legal Med 2017; 131(6):1757-63.
16. Dedouit F, Savall F, Mokrane F-Z, Rousseau H, Crub´ezy E, Roug´e D, et al. Virtual anthropology and forensic identification using multidetector CT. Br J Radiol 2014;87:20130468.
17. Gumusburun E, Yucel F, Ozkan Y, Akgun Z. A study of the nutrient foramina of lower limb long bones. Surg. Radiol Anat 1994; 16:409-12.
18. Collipal E, Vargas R, Parra X, Silva E, Del Sol M. Diaphyseal nutrient foramina in the femur, tibia and fibula bones. Int J Morphol 2007;25:305-8.
19. Kizil Kanat E, Boyan N, Ozsahin ET, et al., Location, number and clinical significance of nutrient foramina in human long bones. Ann. Anat 2007;189: 87-95.
20. Sendemir E, Cimen A. Nutrient foramina in the shafts of lower limb long bones: situation and number. Surg Radiol Anat 1991;13(2):105-8.
21. Forriol CF, Gomez PeL, Gianonatti AM, Fernandez-Valencia R. A study of the nutrient foramina in human long bones. Surg Radiol Anat. 1987;9(3):251-5.
22. Longia GS, Ajmani ML, Saxena SK, Thomas RJ. Study of diaphyseal nutrient foramina in human long bones. Acta Anat (Basel) 1980;107(4): 399-406.
23. Guo F. Fibular blood supply. Chin Med J 1981; 94:396-400.
24. Mckee NH, Haw P, Vettese T. Anatomic study of the nutrient foramen in the shaft of the fibula. Clin Orthop Rel Res 1984;184:141-144