Original Article

DOI: 10.7860/IJARS/2022/43270.2796

Anatomy Section

Morphometric Study of Nutrient Foramina in Typical Adult Human Long Bones of Superior Extremity with its Clinical and Surgical Importance A Cross-sectional Study

UKTIBEN AKHILESHBHAI DESAI[1], BHAVANA KALUBHAI DAMOR[2]

(cc) BY-NC-ND

ABSTRACT

Introduction: The nutrient foramina are the openings which provide passage to the nutrient vessels on the shaft of long bones. Nutrient arteries play a crucial role in development of the bones particularly during its growth period in the embryo and foetus.

Aim: To find out the morphology, topography and variations of nutrient foramina along with their Foraminal Index (FI) in typical adult human long bones of superior extremity.

Materials and Methods: A cross-sectional study was done on 370 typical adult dried human long bones (93 Humerus, 196 Radius and 81 Ulna) of upper extremity which were obtained from the Department of Anatomy, Government Medical College, Baroda, Gujarat, India from January 2016 to June 2019. These samples were studied for the presence of number, location and direction of Nutrient foramen. Total length of the bone with the help of osteometric board and distance of nutrient foramina from upper end were measured with the help of sliding vernier calipers. The FI were also determined with the help of Hughes formula. Data was calculated using Microsoft (MS) Excel 2010 version.

Results: In present study, it was observed that out of 93 humerus, 69 (74.19%) humerus had a single nutrient foramina, 14 (15.05%) had double foramina and 10 (10.75%) had absent nutrient foramen. Single nutrient foramina was present in 174 (88.77%) number of radius, double were observed in 02 (1.02%) and 20 (10.20%) had no nutrient foramina. In case of ulna, 75 (92.93%) were having single, 4 (4.93%) were having double nutrient foramina and 2 (2.46%) had absence of foramina. In present study, nutrient foramina were directed away from the growing end in all typical long bones. All the nutrient foramina in humerus were directed distally, whereas in Radius and Ulna those were directed proximally. Ninety two (85.98%) humerus nutrient foramina were most commonly present in the middle third of humerus bone. In 01 (0.93%) humerus, nutrient foramen was present in the upper third of the bone. In radius, 109 (55.33%) nutrient foramina were present in the middle third while 69 (38.76%) were present in the upper third of the bone. In Ulna, 49 (57.64%), nutrient foramina were present in the middle third and 34 (40%) nutrient foramen they were present in the upper third of the bone.

Conclusion: Knowledge of the morphology, topography and variations of nutrient foramina along with their FI is of clinical importance.

Keywords: Bone grafting, Foraminal index, Hughes formula

INTRODUCTION

Nutrient foramen is an opening into the bone shaft which permits channel to the blood vessels of the medullary cavity of the bone for its sustenance and progressive ossification [1]. The nutrient artery is the chief source of vascular supply to a long bone and is mainly important during its growth period in the embryo and foetus as well as during the early phase of ossification [2]. The nutrient foramen is directed away from the growing end of the bone. The growing end of bone in upper limb is upper end of humerus and lower end of radius and ulna. Nutrient foramen is directed near elbow in upper limb (directed towards lower end of humerus and upper ends of radius and ulna) while in lower limb it is directed away from knee (upper end of femur and lower ends of tibia and fibula), this is said to be due to one end of limb bones growing faster than the other. The structural knowledge of these nutrient foramina is useful in operative procedures to preserve the vascular supply of the bone [3-5].

The study of nutrient foramina is important in both morphological and clinical aspects. The blood supply is extremely vital for any long bones and it should be preserved in order to promote the healing of fracture. In addition, injury to the growing end in young age makes the bone stunted [6]. The nutrient blood supply is necessary for the survival of the osteocytes in cases of tumour resection, trauma and congenital pseudoarthrosis [7].

The aim of the study was to find out the morphology, topography and variations of nutrient foramina along with their Foraminal Index (FI) in typical adult human long bones of superior extremity in Gujarat region.

MATERIALS AND METHODS

The present cross-sectional study was conducted in the Department of Anatomy, Government Medical College, Baroda, Gujarat, India, from January 2016 to June 2019. The Institutional Ethics Committee (IEC) approval was obtained (IECBHR/128-2021). Total 370 typical long bones of human upper limb (93 humerus, 196 radius, 81 ulna) were observed and studied.

Inclusion criteria: All the normal and intact typical long adult human bones of upper limb were included in the study.

Exclusion criteria: Those bones which were damaged or pathologically abnormal were excluded from the study.

Procedure

The bones for investigation were washed properly, cleaned and dried. Each bone was studied for presence of number, position and direction of nutrient foramen. The nutrient foramen was recognised by presence of a noticeable groove and elevated edges at the beginning of the canal. The precise position of the nutrient foramen was made out whether it was present on the upper, middle or the lower one third of the bone. The total length of long bones and distance of nutrient foramen from the upper end were noted using sliding calliper and osteometric board [Table/Fig-1].

Proximal end of the bone

Proximal end of humerus, radius and ulna were marked to be the highest point of upper end for measurements. [Table/Fig-1] proximal end of radius was marked from the highest point of upper end.

Direction: A fine pin with a flag was used to confirm the direction and obliquity of foramen.

Position: Position of all nutrient foramina was determined by calculating the FI using the Hughes formula [8]:

FI= (DNF/TL) * 100

DNF= the distance from the proximal end of the bone to the nutrient foramen

TL= Total Bone Length

The position of the foramina was divided into three types according to FI [8]:

FI= (DNF/TL) * 100

Type I: FI below 33.33, the foramen was in the proximal third of the bone.

Type II: FI from 33.33 up to 66.66, the foramen was in the middle third of the bone.

Type III: FI above 66.66, the foramen was in the distal third of the bone.

The number of nutrient foramina were noted. [Table/Fig-2] depicts humerus showing double nutrient foramina on the anteromedial suface in middle third.

[Table/Fig-1]: Left humerus showing method of taking measurements of distance of nutrient foramen from the upper end (proximal end of bone) using osteometric board and sliding vernier calliper. **[Table/Fig-2]:** Left humerus showing double nutrient foramen on the anteromedial surface in the middle third of the shaft (Type II). (Images from left to right)

STATISTICAL ANALYSIS

Data was calculated as means and standard deviations for continuous variables, and percentage for categorical variables.

RESULTS

Total 93 humerus studied, of which 44 were right-sided bones and 49 were left-sided bones. Total 196 radius studied, 95 were left-sided and 101 were right-sided. Out of 81 ulnas, 35 were right-sided and 46 were left-sided. In present study, double nutrient foramina were observed in humerus in 14 bones (15.05%) [Table/Fig-2,3], Whereas in radius only 02 bones (1.02%) were having double nutrient foramina, while in ulna, it was found in 04 bones (4.93%) [Table/Fig-3]. The DNF for right humerus was 18.58±4.05, TL was 30.08±1.78 and FI was 53.27, respectively [Table/Fig-4].

Bone	Number of foramina (n)	Number of bones (n)
Humerus (N=93)	0	10 (R-4, L-6)
	1	69 (R-34, L-35)
	2	14 (R-6, L-8)
Radius (N=196)	0	20 (R-10, L-10)
	1	174 (R-90, L-84)
	2	02 (R-1, L-1)
Ulna (N=81)	0	02 (R-1, L-1)
	1	75 (R-33, L-42)
	2	04 (R-1, L-3)

[Table/Fig-3]: Number of nutrient foramina in typical long bones of upper limb.
R: Right; L: Left

Parameters analysed	Humerus (N=93)		Radius (N=196)		Ulna (N=81)	
	Right (n=44)	Left (n=49)	Right (n=101)	Left (n=95)	Right (n=35)	Left (n=46)
DNF (mm)	18.58± 4.05	18.78± 4.83	7.33± 2.62	7.57± 2.85	8.62± 2.30	8.89± 2.65
TL (mm)	30.08± 1.78	30.23± 2.08	23.54± 1.58	23.45± 1.74	25.25± 1.85	25.22± 1.85
FI	53.27	49.96	31.25	32.08	34.10	30.83

[Table/Fig-4]: Foraminal Index (FI) and measurements related with nutrient foramina in typical long bones of superior extremity.
DNF= Distance from the proximal end of the bone to the nutrient foramen; TL= Total length of the bone; FI = Foraminal index

Ninety two number (94.85%) of humerus nutrient foramina were most commonly present in the middle third of humerus bone (1.03%). In one humerus, nutrient foramen was present in the upper third of the bone. In Radius, 109 (61.58%), nutrient foramina were present in the middle third and in 69 (38.76%) were present in the upper third of the bone. In Ulna, 49 (59.04%) nutrient foramina were present in the middle third and 34 (40.96%) nutrient foramina were present in the upper third of the bone. In radius and ulna, no nutrient foramen was found to be present in the distal third of the bone where as in humerus, it was found to be in 4 bones (4.12%) [Table/Fig-5]. All the nutrient foramina in humerus were directed distally, whereas in radius and ulna those were directed proximally.

Foraminal index (FI)	Humerus (Total number of nutrient foramina= 97)	Radius (Total number of nutrient foramina= 178)	Ulna (Total number of nutrient foramina= 83)
Type I (<33.33%)	01 (1.03%)	69 (38.76%)	34 (40.96%)
Type II (33.34-66.6%)	92 (94.85%)	109 (61.58%)	49 (59.04%)
Type III (>66.67%)	04 (4.12%)	0	0

[Table/Fig-5]: Classification of location of foramina of the bones on the basis of Foraminal Index (FI).

DISCUSSION

The knowledge of diversity of nutrient foramina has profound importance in orthopaedic surgeries for undertaking an open reduction of a fracture to avoid injury to the nutrient artery and thus lessening the chances of delay or non union of the fractures [9]. An arterial supply of long bone should be preserved as it is very important for healing of a fractured bone [10].

Number of nutrient foramina:

The present study show that single nutrient foramen was present in 74.19% of humerus, which is similar to Chandrasekaran S and Shanthi KC and nearly similar finding was found by Carroll SE and Ukoha UU et al., [11-15]. The incidence was found to be higher in a study done by Roul B and Goyal M, as compared to present study which suggests the possibility of regional variations in morphology of bones [14]. Present study showed that prevalence of double nutrient foramina were found in 15.05% of humerus which is in accordance to the findings of Chandrasekaran S and Shanthi KC; Halagatti MS and Rangasubhe P, [11,13]. In the study done by Ukoha UU et al., 26% of humerus showed absent nutrient foramina, in such cases the periosteal blood vessels was entirely responsible for the blood supply of the bone [15]. This is in accordance to the report of this present study as 10.75% of humeri observed were without nutrient foramina [Table/Fig-6] [9,11-14].

Variables studied	Chandrasekaran S and Shanthi KC [11]	Carroll SE [12]	Halagatti MS and Rangasubhe P, [13]	Roul B and Goyal M [14]	Joshi H et al., [9]	Present study
Number of bones analysed	258	71	200	37	200	93
Single nutrient foramina	198 (76.74%)	48 (68%)	161 (80.5%)	35 (94.6%)	126 (63%)	69 (74.19%)
double nutrient foramina	53 (20.54%)	20 (28%)	35 (17.5%)	2 (5.4%)	66 (33%)	14 (15.05%)
Triple nutrient foramina	07 (2.71%)	03 (04%)	04 (02%)	0	08 (04%)	0
Absent nutrient foramina	0	0	0	0	0	10 (10.75%)

[Table/Fig-6]: comparison of various studies with regard to number of nutrient foramina in humerus [9,11-14].

In case of radius, 88.77% bones were having single nutrient foramen, similarly, in other studies too, majority of the radius were found to possess a single nutrient foramen [Table/Fig-7] [14-18]. In most of the other studies, radius with absent nutrient foramina was not observed while in this study, it was observed to be 10.20% [Table/Fig-7,8]. In present study, double nutrient foramina were present in 04 (4.93%) number of ulna which was less than found by Patel SM and Vora RK, and higher than other studies as shown in [Table/Fig-7,9] [17].

Bones studied	Number of nutrient foramen	Reddy G et al., [16]	Ukoha UU et al., [15]	Roul B and Goyal M, [14]	Patel SM and Vora RK, [17]	Pereira GA et al., [18]	Present study
Radius	Single nutrient foramen	96.3%	68%	97%	100%	99.4%	88.77%
	Double nutrient foramen	3.7%	0	03%	0	0.6%	1.02%
	Absent nutrient foramen	0	32%	0	0	0	10.20%
Ulna	Single nutrient foramen	100%	78%	96%	92.5%	98.6%	92.93%
	Double nutrient foramen	0	0	02%	7.5%	1.4%	4.93%
	Absent nutrient foramen	0	22%	02%	0	0	2.46%

[Table/Fig-7]: indicates comparison of number of nutrient foramina in Radius and Ulna with other studies [14-18].

Location of nutrient foramina: The present study showed that the majority of nutrient foramina (85.98%) were found to be present in middle third of the humerus (according to Hughes formula Type II) which correlated well with the study conducted by Chandrasekaran S and Shanthi KC (86.43%) [11]. In Radius, in 55.33% cases, nutrient foramina were present in the middle third and 34.51% were present in the upper third of the bone. Similar observation was reported by Ukoha UU et al., [15]. In their study, it was found to be 57.1% in upper third and 42.9% in the middle third of Radius. In present

[Table/Fig-8]: A Photograph of a right radius showing absent nutrient foramen.
[Table/Fig-9]: A Photograph of a right ulna showing double nutrient foramen on anterior surface. (Images from lleft to right)

study, in Ulna, 57.64% bones presented nutrient foramina in the middle third and 40% presented in the upper third of the bone which corresponds to Roul B and Goyal M, that was found to be 62.16% bones presented nutrient foramina in the middle third and 32.43% presented in the upper third of the bone [14]. The knowledge of the position and number of the nutrient foramina in long bones is essential for orthopaedic surgeons during surgeries such as joint replacements, fractures repair, bone grafting procedures.

Limitation(s)

Present study is an osteological study and comparison with radiological studies is not done. This study has certain limitations such as number of bones which are variable and regional variations may be also there.

CONCLUSION(S)

Knowledge of the location, number and direction of the nutrient foramen is not only important in understanding the development of bone but also important in orthopaedic surgeries like microvascular bone grafting procedures by avoiding injury to nutrient vessels.

REFERENCES

[1] Malukaralukar O, Joshi H. Diaphysial nutrient foramina in long bones and miniature long bones. NJIRM. 2011;2(2):23-26.
[2] Kizilkanat E, Boyan N, Ozsahin ET, Soames R, Oguz O. Location, number and clinical significance of nutrient foramina in human long bones. Ann Anat. 2007;189(1):87-95.
[3] Henderson RG, The position of the nutrient foramen in the growing tibia and femur of the rat. J Anat. 1978;125(Pt 3):593-99.
[4] Mysorekar VR. Diaphysial nutrient foramina in human long bones. J Anat. 1967;101(Pt4):813-22.
[5] Taylor GI, Fibular transplantation. In: Serafin D, Bunke HJ (eds), Microsurgical composite tissue transplantation, C.V. Mosby Co., St. Louis,1979; 418-423.
[6] Longia GS, Ajmani ML, Saxena SK, Thomas RJ. Study of diaphyseal nutrient foramina in human long bones. Acta Anat. 1980;107(4):399-406.
[7] Sendemir E, Cimen A. Nutrient foramina in the shafts of lower limb long bones: situation and number. Surg Radiol Anat. 1991;13(2):105-08.
[8] Hughes H. The factors determining the direction of the canal for the nutrient artery in the long bones of mammals and birds. Acta Anat. 1952;15(3):261-80.
[9] Joshi H, Doshi B, Malukar O. A study of the nutrient foramina of the humeral diaphysis. National Journal of Integrated Research in Medicine. 2011;2(2):14-17.
[10] Hoy WE, Hughson MD, Bertram JF, Douglas-Denton R, Amann K. Nephron number, hypertension, renal disease, and renal failure. J Am Soc Nephrol. 2005;16(9):2557-64.
[11] Chandrasekaran S, Shanthi KC. A study on the nutrient foramina of adult humerii. Journal of Clinical and Diagnostic Research: JCDR. 2013;7(6):975-77. doi:10.7860/JCDR/2013/5983.3095.

[12] Carroll SE. A study of the nutrient foramina of the humeral diaphysis. J Bone Joint Surg. 1963;45:176-81. doi: 10.1302/0301-620X.45B1.176

[13] Halagatti MS, Rangasubhe P. A study of nutrient foramina in dry adult humeri in south Indian subjects. National Journal of Clinical Anatomy. 2011;1(2):76-80.

[14] Roul B, Goyal M. A study of nutrient foramen in long bones of superior extremity in human being. International Journal of Current Research in Life Sciences. 2015;4(4):198-200.

[15] Ukoha UU, Umeasalugo KE, Nzeako HC, Ezejindu DN, Ejimofor OC, Obazie IF. A study of nutrient foramina in long bones of Nigerians. Natl J Med. 2013;3(4):304-08.

[16] Reddy GRMK, Siddaramulu C, Bilodi AKS. Morphometric study of the nutrient foramina of unknown radius and ulna and their clinical importance in the region of Kadapa [Rayalaseema].Andhra Pradesh J Evid Based Med Healthc. 2016;3(27):1222-29.

[17] Patel SM, Vora RK. Anatomical study of nutrient foramina in long bones of human upper limbs. IAIM. 2015;2(8):94-98.

[18] Pereira GA, Lopes PT, Santos AM, Silveira FH. Nutrient foramina in the upper and lower limb long bones: Morphometric study in bones of southern Brazilian adults. Int J Morphol. 2011;29(2):514-20.

PARTICULARS OF CONTRIBUTORS:

1. Tutor, Department of Anatomy, Baroda Medical College, Vadodara, Gujarat, India.
2. Tutor, Department of Anatomy, Baroda Medical College, Vadodara, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Bhavana Kalubhai Damor,
B-65, Siddheshwar Holy Homes, Opposite Rudraksh Rivera, B/H Sayaji Township,
New V.I.P. Road, New Karelibaugh, Vadodara, Gujarat, India.
E-mail: damorbhavana8@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Nov 25, 2021
- Manual Googling: Feb 21, 2022
- iThenticate Software: Mar 08, 2022 (25%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval Obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Nov 23, 2021**
Date of Peer Review: **Jan 03, 2022**
Date of Acceptance: **Feb 23, 2022**
Date of Publishing: **Jul 01, 2022**