International Journal of Anatomy and Research,
Int J Anat Res 2017, Vol 5(3.3):4394-99. ISSN 2321-4287
DOI: https://dx.doi.org/10.16965/ijar.2017.348

Original Research Article

NUTRIENT FORAMINA: A STUDY IN THE LONG BONES OF HUMAN UPPER EXTREMITIES

Veeramuthu. M [1], Elangovan. M *[2], Manoranjitham [3].

[1] Assistant Professor, Department of Anatomy, Dhanalakshmi Srinivasan Medical College & Hospital, Perambalur, Tamil Nadu, India.

*[2] Associate Professor, Department of Anatomy, Dhanalakshmi Srinivasan Medical College & Hospital, Perambalur, Tamil Nadu, India.

[3] Professor and Head, Department of Anatomy, Dhanalakshmi Srinivasan Medical College & Hospital, Perambalur, Tamil Nadu, India.

ABSTRACT

Background: Nutrient foramen is a natural opening in the shaft of a bone, allowing for passage of blood vessels into the medullary cavity. The knowledge of nutrient foramen is important in surgical procedures like bone grafting and more recently in microsurgical vascularised bone transplantation.

Materials and Methods: This study was conducted in 173 long bones of the upper limb (55- humerus, 59- radius, 59-ulna). The number, location, size, position and direction of the diaphysis nutrient foramen in each of the long bones was noted. The foraminal index was also calculated using the Hughes formula.

Results: In humerus single nutrient foramen was present in 84% of the bones, double nutrient foramina in 14% of the bones and had no nutrient foramina in 2% of the bones. The most common location of the nutrient foramina in humerus was in Antero medial surface, which was noted in 74% of the bones and in 89% of the bones the nutrient foramen was located in the middle third of the shaft of humerus. In radius, single nutrient foramen was found in 97% of the bones and double nutrient foramina were found in 3% of the bones. The most common location of the nutrient foramen in radius was on the anterior surface, which was noted in 72% of the bones and in 59% of the bones, the nutrient foramen was located in the middle third of the shaft of radius. In ulna, single nutrient foramen was found in 96% of the bones and double nutrient foramina were found in 2% of the bones and had no nutrient foramina in 2% of the bones The most common location of the nutrient foramen in ulna was on the anterior surface, which was noted in 76 % of the bones and in 68% of the bones the nutrient foramen was on the middle third of the shaft of ulna.

Conclusion: The precise anatomical knowledge of the nutrient foramen of the long bones of upper limb is important for orthopaedic surgeons during surgical procedures like bone grafting, microsurgical bone transplantation.

KEY WORDS: Nutrient Foramen, Long Bones, Foramina Index, Variation In Position, Location, Number, Size.

Address for Correspondence: Elangovan. M, Associate Professor, Department of Anatomy, Dhanalakshmi Srinivasan Medical College & Hospital, Tiruchi -Chennai Highway, Siruvachur, Perambalur, Tamil Nadu 621113, India. **E-Mail:** veera3071985@gmail.com.

Access this Article online

Quick Response code	Web site: International Journal of Anatomy and Research ISSN 2321-4287 www.ijmhr.org/ijar.htm	
DOI: 10.16965/ijar.2017.348	Received: 15 Jul 2017 Peer Review: 15 Jul 2017 Revised: None	Accepted: 16 Aug 2017 Published (O): 30 Sep 2017 Published (P): 30 Sep 2017

INTRODUCTION

Nutrient foramen is an opening in the bone shaft which gives passage to the blood vessels of the medullary cavity of a bone for its nourishment and growth [1]. The nutrient artery is the principal source of blood supply to a long bone and is particularly important during its active growth period in the embryo and fetus, as well as during the early phase of ossification [2]. The nutrient artery enters individual bones obliquely through a nutrient foramen [3]. Nutrient foramen are directed towards elbow in upper limb (directed towards lower end of humerus and upper ends of radius and ulna),while in lower limb nutrient foramen is directed away from knee (that is, upper end for 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 and generally follows the rule, "to the elbow I go, from the knee I flee." Their positions in mammalian bones are variable and may alter during the growth phase.

The topographical knowledge of these nutrient foramina is useful in operative procedures to preserve the circulation. [4-6]. Humphrey was working on the direction and obliquity of nutrient canals postulated periosteal slipping theory, the canal finally directed away from the growing end. [7]. Nutrient artery is the major source of blood supply to the bone and hence plays an important role in fracture healing. Orthopaedic surgical procedures like vascularized bone microsurgery requires the detailed knowledge of the blood supply. In free vascular bone grafting, the blood supply by nutrient artery is extremely important and must be preserved in order to promote fracture healing [8].

Study of nutrient foramina in upper limb is very important for morphological, clinical, and pathological point of view. Fracture healing or hematogenic osteomyelitis is closely related to the vascular system of the bone.[9]. Detailed data on the blood supply to the long bones is invariably crucial in the development of new transplantation and resection techniques in orthopaedics [2,10].

MATERIALS AND METHODS

The present study was conducted in the Department of Anatomy, DhanalakshmiSrinivasan Medical College and Hospital Perambalur, Tamilnadu. This study was approved by the Institutional Research (No.IRCHS/DSMCH/057, date 26th October 2016) and Ethics Committee (No.IECHS/DSMCH/041, date 19th November 2016) (Human study) of Dhanalakshmi Srinivasan Medical College and Hospital, Perambalur, Tamilnadu. The materials for the present study consisted of 173 adult human cleaned and dried bones of the upper limbs. They were divided into three groups: 55 bones of humerus and 59 bones each of ulna and radius. All selected bones were normal with no appearance of pathological changes. The specific age and sex characteristics of the bones studied were unknown.

Objectives: To observe number of foramina on the shaft of a bone, To observe Surface on which it was located, To note Direction of nutrient foramina from growing end, To observe Location in relation with length of the shaft.

The nutrient foramina were observed in all bones with the help of a hand lens. They were identified by their elevated margins and by the presence of a distinct groove proximal to them. Only well-defined foramina on the diaphysis were accepted. Foramina at the ends of the bones were ignored.

Size of nutrient foramina: The size of nutrient foramen was determined by using hypodermic needles no. 26& 22.

Large foramen – accepted the no.26 needle.

Medium foramen – accepted only the no.22 needle.

Small foramen – did not take no.22 needle.

Direction of nutrient foramina: A fine stiff broomstick was used to confirm the direction and obliquity of the foramen.

Position of nutrient foramina: The distance of the dominant nutrient foramen (DNF) from the highest point of the proximal part of the long bones was measured with a vernier calipers. The total length (TL) of the bone was measured using an osteometric board.The position of all nutrient foramina was determined by calculating the foraminal index (FI) using the formula: FI = (DNF/TL) x 100

Where DNF=the distance from the proximal end of the bone to the nutrient foramen; TL=Total bone length [11].

The position of the foramina was divided into three types according to FI as follows:

Type 1: FI below 33.33, the foramen was in the proximal third of the bone.

Type 2: FI from 33.33 up to 66.66, the foramen was in the middle third of the bone.

Type 3: FI above 66.66, the foramen was in the distal third of the bone.

All the observations were carefully tabulated and statistically analysed using Microsoft excel worksheet.

RESULTS

Number of nutrient foramina observed: In humerus, single nutrient foramen was observed in 84% of the bones, double nutrient foramina (Figure 1) was observed in 14% of the bones and had no nutrient foramina was observed in 2% of the bones (Table 1).

In radius, single nutrient foramen was observed in 97% of the bones and double nutrient foramina (Figure 2) were observed in 3% of the bones (Table 1).

In ulna, single nutrient foramen was observed in 96 % of the bones,double nutrient foramina (Figure 3) were observed in 2% of the bones and had no nutrient foramina was observed in 2% of the bones (Table 1).

Table 1: Number of nutrient foramina observed in the long bones of the upper limb.

Bone	Number of foramina	Number of bones (%)
Humerus (n=55)	Absent	1 (2)
	1	46 (84)
	2	8 (14)
Radius(n=59)	Absent	–
	1	57 (97)
	2	2 (3)
Ulna(n=59)	Absent	1 (2)
	1	57 (96)
	2	1 (2)

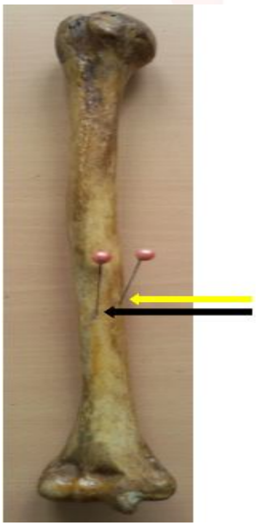

Fig. 1: A photograph of humerus shows double nutrient foramin one in medial border (yellow arrow) and another one in antero medial surface(black arrow).

Nutrient foramina in humerus: All the nutrient foramina observed in humerus were directed distally. 89% of the nutrient foramina were most commonly present in the middle one third of the humerus bone (Table 2). 74% of the nutrient foramina were most commonly located in the anteromedial surface (Table 3).

Table 2: Position and direction of nutrient foramina observed in the long bones of upper limbs.

Bone	Position			Direction
	Type-1	Type-2	Type-3	
Humerus	-	49 (89 %)	5 (10 %)	Distally
Radius	24 (41%)	35 (59%)	-	proximally
Ulna	19 (32%)	40 (68%)	-	proximally

Table 3: Location of nutrient foramina observed in the Humerus.

Location	Number of foramina (%)
Antero medial surface	41 (74)
Medial border	11 (20)
Posterior surface	1 (1)
Radial groove	4 (1)
Anterior border	2 (3)
Absent	1 (1)

Nutrient foramina in radius: All the nutrient foramina observed in radius were directed proximally. 59% of the nutrient foramina were most commonly present in the middle one third of the radius bone.(Table 2). 72% of the nutrient foramina were most commonly located in the anterior surface (Table 4)

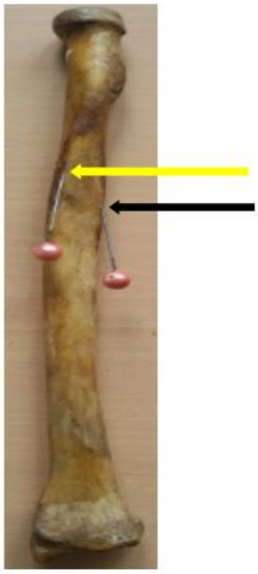

Fig. 2: A photograph of radius shows double nutrient foramina one in medial border (yellow arrow) and another one in anterior border (black arrow).

Table 4: Location of nutrient foramina observed in the Radius.

Location	Number of foramina (%)
Anterior surface	43 (72)
Medial border	7 (11)
Anterior border	6 (10)
Posterior surface	3 (5)

Nutrient foramina in ulna: All the nutrient foramina observed in radius were directed proximally. 68 % of the nutrient foramina were most commonly present in the middle one third of the ulna bone.(Table 2). 76% of the nutrient foramina were most commonly located in the anterior surface (Table 5)

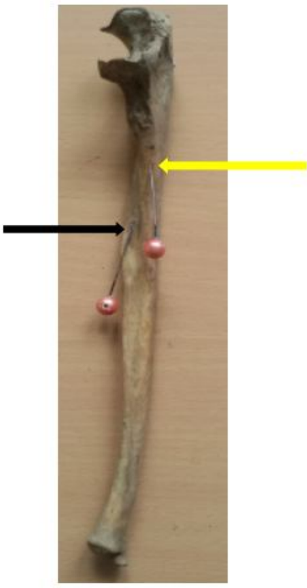

Fig. 3: A photograph of ulna shows double nutrient foramina one in anterior border (yellow arrow) and another one in anterior surface (black arrow).

Table 5: Location of nutrient foramina observed in the ulna.

Location	Number of foramina (%)
Anterior surface	45(76)
Anterior border	9 (15)
Posterior surface	1(2)
Lateral border	3(5)
Absent	1 (2)

Size of nutrient foramina observed:

In humerus, small size nutrient foramina was observed 56.36%, medium size was observed 38.18% and large size was observed 5.45%.In radius, small size nutrient foramina was observed 84.74%,medium size was observed 13.55% and large size was observed 1.69.In ulna,small size nutrient foramina was observed 71.18%,medium size was observed 23.72% and large size was observed 5.08%.(Table 6)

Table 6: size of nutrient foramina observed in the long bones upper limbs.

Size of nutrient foramina (in mm)	humerus		Radius		Ulna	
	Number of nutrient foramina	%	Number of nutrient foramina	%	Number of nutrient foramina	%
Small (> 0.5<0.7)	31	56.36	50	84.74	42	71.18
Medium (>0.7<1.1)	21	38.18	8	13.55	14	23.72
Large (>1.1)	3	5.45	1	1.69	3	5.08

Foraminal index: Data are mean and standard deviation. DNF = Distance from the proximal end of the bone to the nutrient foramen; TL = Total length of bone; FI = Foramen Index.

Table 7: Foramen index and measurements associated with nutrient foramen in the long bones Of the upper limb.

Measurements	Humerus (n=55)	Radius (n=59)	Ulna (n=59)
DNF	17.71±2.2	8.37 ± 1.13	9.71± 1.37
TL	30.03±2.13	24.85 ± 1.40	25.98± 1.23
FI	58.95± 5.63	33.78 ± 4.64	36.39± 5.61

The average total length of humerus was found to be 30.03±2.13 cm. The average distance of the nutrient foramen from the highest point on the proximal part of the bone was 17.71 ± 2.2 cm. The average foraminal index was 58.95 ± 5.63 c.m. The average total length of radius was found to be 24.85 ± 1.40 cm. The average distance of the nutrient foramen from the highest point on the proximal part of the bone was 8.37 ± 1.13 cm. The average foraminal index was 33.78 ± 4.64 c.m. The average total length of ulna was found to be 25.98± 1.23 cm. The average distance of the nutrient foramen from the highest point on the proximal part of the bone was 9.71± 1.37 cm. The average foraminal index was 36.39± 5.61 c.m.(Table 7).

DISCUSSION

Number of Nutrient Foramina: In our study, a single nutrient foramen had a higher percentage (84%) in the humeral bones, compared to that of double (14%).Many studies reported a percentage approximately similar to that of the present result [12,5].The range of occurrence of double foramina varied from 13% [13]to 26% [14] and 42% [5]. Also, some reported the absence of nutrient foramina in some humeri [1, 2]; they stated that in such cases, the periosteal vessels were entirely responsible for the blood supply of the bone. This is in accordance to the report of this present study as 2% of humeri observed were without nutrient foramen (Table1).

In the present study total 97% of the radius examined had a single nutrient foramen (Table 1). In other studies, the majority of radii more than 90% were found to possess a single nutrient foramen [2, 16].

The absence of nutrient foramina in the long bones is well known. [5,15,16] In the present study, we did not found any radii with the absence of the nutrient foramina.Gotzen, N et al and Gumusburun, E et al [17, 18] were noted a single nutrient foramen in more than 91% of ulnae. This corresponds with the observations in the ulnae in the present study (Table 1).

Position of Nutrient Foramina: In our study, most of tnutrient foramina were located along the middle third of the humerus (Table 2) which was correlated with other studies [2,19,20] Also, 74% of all humeral nutrient foramina were observed on the anteromedial surface of the bone (Table 3). Similar findings had been reported by Kizilkanat et al. [2] ,Kumar et al [14], and Ukoha Ukoha Ukoha et al [21]. Mysoreker VR [5] and Caroll SE [22] in their studies stated that surgery or fracture in distal and middle 1/3 of the shaft of the humerus leads to the poor healing compared to fracture of proximal half of the bone which is unlikely to compromise the blood supply.

In our study, 59% of the total nutrient foramina were noted most often in the middle third of the radius and 41% were in the proximal third. No nutrients foramina were detected in the distal third of radius(Table 2).The ratios of the present study were close to those reported by Mysorekar (1967) who found 62% of foramina located in the middle third of the bone and 36% in the proximal end [5]. Similar findings had been reported by Anusha P et al [23].In the present study, 72% of all radial foramina were on the anterior surface, of the bone. Such results were in accordance with the previous studies [19] who stated that the majority of nutrient foramina were located on the anterior surface of the bone.

In the present study, the majority of nutrient foramina (68%) were in the middle third while 32% were in the proximal third of the ulna bone (Table 2). No nutrient foramina were detected in the distal third of the ulnae. Some authors reported that the majority of nutrient foramina were located in the middle third [5] while others stated that most of foramina were in the proximal third [13,14]. However, all agreed that there were no nutrient foramina in the distal third of the ulna. Also, 72 % of the nutrient foramina were located on the anterior surface of the ulnae (Table 5). In all previous studies, the nutrient foramina were mostly observed on the anterior surface of the ulna [2, 10].

Direction of Nutrient Foramina: In this study, all the nutrient foramina in humerus were directed distally (away from the growing ends). In the radii examined, the direction of the nutrient foramina was proximal (Table 2). The nutrient foramina of all ulnae examined had a proximal direction. This is similar to the study done by Ukoha Ukoha Ukoha[21] and Kumar et al [14], only that the variation was seen in the radius and humerus.

Size of foramina: In the present study, the size of the majority of nutrient foramina was small in humerus,radius and ulna (Table 6).size of nutrient foramina in radius majority was medium. This study done by pramod rangasubhe et al [24].There was no comparative study of size of nutrient foramina for humerus and ulna.

Clinical Relevance: An understanding of the position and number of the nutrient foramina in long bones is important in orthopaedic surgical procedures such as joint replacement therapy, fracture repair, bone grafts and vascularized bone microsurgery [2]. The foramen may be a potential area of weakness in some patients and, when under stress because of increased physical activity or decreased quality of the bone, the foramen may allow development of a fracture. Position of the fracture relative to the nutrient foramen of the long bone and the patterns of edema are the secondary signs in the key of the diagnosis of this type of fracture [25].

CONCLUSION

The study confirmed previous reports regarding the number and position of the nutrient foramina in the long bones of the limbs. It also provided important information to the clinical significance of the nutrient foramina. The anatomical data of this subject is enlightening to the clinician as the microvascular bone transfer is becoming more popular.

Conflicts of Interests: None

REFERENCES

[1]. Malukar 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, E. T.; Soames, R. & Oguz, O. Location, number and clinical significance of nutrient foramina in human long bones. Ann. Anat., 2007; 189:87-95.

[3]. Henderson RG. The position of the nutrient foramen in the growing tibia and femur of the rat. J Anat 1978;125(pt 3):593-599.

[4]. Henderson RG, The position of the nutrient foramen in the growing tibia and femur of the rat, J Anat, 1978, 125(Pt 3):593–599.

[5]. Mysorekar VR, Diaphysial nutrient foramina in human long bones, J Anat, 1967, 101(Pt4):813–822.

[6]. Taylor GI, Fibular transplantation. In: Serafin D, Bunke HJ (eds), Microsurgical composite tissue transplantation, C.V. Mosby Co., St. Louis,1979;418-423.

[7]. Harris HA. Bone Growth in Health and Disease. London, Humphrey Milfords. 1933.

[8]. Yaseen S, Nitya W, Ravinder M. Morphological and Topographical study of Nutrient foramina in adult humerii. International journal of innovative research and development 2014;3(4):07-10.

[9]. Skawina A., Wyczolkowski M. Nutrient foramina of humerus, radius and ulna in Human Fetuses. Folia Morphol., 1987;46: 17–24.

[10]. Kirschner, M. H.; Menck, J, Hennerbichler, A., Gaber, O. & Hofmann, G. O. Importance of arterial blood supply to the femur and tibia transplantation of vascularized femoral diaphiseal and knee joints. World J. Surg., 1998;22:845-52.

[11]. Shulman, S. S. Observations of the nutrient foramina of the human radius and ulna. Anat. Rec. 1959;134:685-97.

[12]. Forriol Campos, F., Gomez Pellico, L., Gianonatti Alias, M.,Fernandez-Valencia, R. A study of the nutrient foramina in human long bones. Surg. Radiol. Anat. 1987;9:251 – 255.

[13]. Longia, G.S., Ajmani, M.L., Saxena, S.K., Thomas, R.J. Study of diaphyseal nutrient foramina in human long bones. Acta Anat.(Basel) 1980;107:399-406.

[14]. Kumar, S; Kathiresan, K; Gowda, M.S.T; Nagalaxmi. Study of Diaphysial Nutrient Foramina In Human Long Bones.Anatomica Karnataka, 2012;6(2):66-70.

[15]. Lutken P, Investigation into the position of the nutrient foramina and the direction of the vessel canals in the shafts of the humerus and femur in man, ActaAnat (Basel), 1950;9(1–2):57–68.

[16]. Murlimanju B.V, Prashanth K.U, Latha V.P, Vasudha V.S, Mangala M.P, Rajalakshmi R. Morphological and topographical anatomy of nutrient foramina in human upper limb long bones and their surgical importance. Rom J Morphol Embryol 2011;52(3):859–862.

[17]. Gotzen, N., Cross, A., Ifju, P., Rapoff, A. Understanding stress concentration about a nutrient foramen. J. Biomech. 2003;36:1511-1521.

[18]. Gumusburun, E., Adiguzel, E., Erdil, H., Ozkan, Y., Gulec, E. A study of the nutrient foramina in the shaft of the fibula. Okajimas Folia Anat. Jpn.1996;73(2-3):125-128.

[19]. Nagel A. The clinical significance of the nutrient artery. Orthop. Rev, 1993; 22:557–561.

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

[21].Ukoha Ukoha Ukoha, Kosisochukwu Emmanuel Umeasalugo1, Henry C Nzeako1, Damian N Ezejindu1, Obioma C Ejimofor1, Izuchukwu F Obazie A study of nutrient foramina in long bones of Nigerians. National journal of medical research 2013;3(4).

[22]. Caroll SE. A study of nutrient foramina of the humeral diaphysis. J Bone Joint Surg 1963;45-3(1);176-81.

[23]. Anusha P, Naidu MP. A study on the nutrient foramina of long bones. *Jour of Med Sc & Tech 2013*;2(3):150-157.

[24].Pramod Rangasubhe,Sheela sivan.A study of nutrient foramina in dry adult radii of south indian subjects.National Journal of Clinical Anatomy. 2014;3(2):71-75.

[25]. Craig, J.G., Widman, D., van Holsbeeck, M. Longitudinal stress fracture: patterns of edema and the importance of the nutrient foramen. Skeletal Radiol. 2003;32:22-27.

How to cite this article:

Veeramuthu. M, Elangovan. M, Manoranjitham. NUTRIENT FORAMINA: A STUDY IN THE LONG BONES OF HUMAN UPPER EXTREMITIES. Int J Anat Res 2017;5(3.3):4394-4399. **DOI:** 10.16965/ijar.2017.348