International Journal of Current Research and Review
DOI: http://dx.doi.org/10.31782/IJCRR.2019.11154

Research Article

IJCRR
Section: Healthcare
Sci. Journal Impact Factor: 5.385 (2017)
ICV: 71.54 (2015)

A Study on the Anatomical Variations in Diaphyseal Nutrient Foramina of Humerus and its Clinical Implications

Chintala Durga Sukumar

Associate Professor, Department of Anatomy, Nimra Institute of Medical Sciences, Ibrahimpatnam, Vijayawada, Andhra Pradesh, India.

ABSTRACT

Aim: The study is aimed to determine number, location and direction of nutrient foramen, to assess whether nutrient foramen obeys rule of ossification, that is directed away from the growing end of the bone or not.

Methodology: The study constituted n = 122 (68 right, 54 left) humeri collected from the Department of Anatomy, Nimra Institute of Medical Sciences, Vijayawada, Andhra Pradesh, India. All the measurements were taken using standard anthropometric techniques.

Results: Number, direction and location of nutrient foramen in relation with surfaces and zones of humeri were determined. Majority 79.51% of the humeri had single nutrient foramen, 13.93% double, 3.28% triple, whereas 3.28% humeri no nutrient foramina. Majority 85.24% of the nutrient foramina were located on antero-medial surface, followed by 10.65% on posterior surface and 6.56% on anterolateral surface of shaft of the humerus. In majority 85.24% of bones foramina were present in zone II, followed by zone I (9.02%), then zone III (5.74%). All foramina were found to be directed towards the lower end of humeri.

Conclusion: The results confirm that the knowledge of the number and position of the nutrient foramina in humerus would be very useful in providing clinical information in preventing intra-operative injury of nutrient artery during orthopedic surgeries and will be relevant as reference for surgical procedures.

Key Words: Clinical implications, Foraminal index, Humerus, Nutrient foramen

INTRODUCTION

Humerus is largest and longest bone of upper limb and is supplied by a nutrient artery which is a branch of brachial artery. The nutrient foramen is an opening on the surface bone into the shaft of humerus bone, passing through cortex, ultimately opens into the medullary cavity. The main nutrient foramina is usually located on antero-medial surface of the humerus a little below its midpoint directed downwards [1], opens close to medial border, although various variations have been reported in number and position of the foramina [2].

Henderson [3] also reported that their location in mammalian bones are variable and may alter during the growth. Any manipulation in this area in the form of close or open reduction may cause damage to nutrient arteries, leading to non-union or delayed union

The nutrient artery of the humerus arises from the brachial artery, enters the shaft divides into ascending and descending branches in the medullary cavity and supply bone marrow and inner two-thirds of cortex of the humerus [4]. The diaphyseal nutrient artery is the main source of blood supply to long bones, especially during active growth period and the early stages of ossification [2] and it should be preserved in order to promote the fracture healing [5]. Moreover, the presence of preserved nutrient blood supply is essential for the survival of osteocytes in cases of tumor resection, trauma, and congenital pseudoarthrosis [6]. Nutrient arteries play important role particularly during active growth period in the embryo and fetus, uniting callus formation in fractured bone [1].

The knowledge regarding the number and location of nutrient foramen helps the surgeon to avoid these complications

Corresponding Author:
Dr. Chintala Durga Sukumar, MD Anatomy, Associate Professor, Department of Anatomy, Nimra Institute of Medical Sciences, Ibrahimpatnam, Vijayawada, Andhra Pradesh, India; Mob: 9441991310; Email: chdsukumar@gmail.com

ISSN: 2231-2196 (Print) **ISSN:** 0975-5241 (Online)

Received: 02.05.2019 **Revised:** 11.06.2019 **Accepted:** 16.07.2019

during certain surgical procedures like bone grafting and microsurgical vascularized bone transplantation [7] and manipulation in the fracture of humerus [8,9].

Though studies on the vascularization of long bones of various populations were conducted, the nutrient foramina of humeri among Andhra Pradesh population was rarely studied.

This study was aimed at analyzing diaphyseal nutrient foramina with reference to variation in number, location, position and direction of nutrient foramina of the humerus of Andhra Pradesh population.

The aim of the present study was to determine any variations in number, direction and location of nutrient foramen in humerus of Andhra Pradesh population and see whether the nutrient foramina obey the general rule that is, directed away from the growing end of the bone.

MATERIALS AND METHODS

The present study was conducted consisting of 122 (68 right and 54 left) dried and cleaned humeri collected from the Department of Anatomy, Nimra Institute of Medical Sciences, Vijayawada, Andhra Pradesh, India. All the bones were of adults (>20 years) and of unknown sex. The size determination was done for the entire material collected. All the humeri taken for the study were normal and with any fracture or pathological abnormalities was excluded from the study. Prior approval was taken from the College Ethical Committee to conduct the study.

In each humerus, the nutrient foramen was examined and studied carefully under proper illumination for number, location and direction of nutrient foramina on its diaphysis. A magnifying lens was used to observe the foramina.

Osteometric board with sliding caliper, magnifying lens, scale and alpin were used for measuring the required parameters.

Nutrient foramina (NF) was identified by the presence of a well-marked groove leading to the foramen, and by a well-marked often slightly raised margins at the edge of the foramen at the commencement of the canal. Only well-defined foramina on the diaphysis were accepted. Foramina at the ends of the bones were ignored.

Location of NF in relation with surface and borders were observed and recorded. Direction of NF in relation with growing end of humerus was observed and noted by inserting an alpin.

Total length of each bone and distance from proximal end of bone to each NF was measured with the help of osteometric board and sliding caliper in millimeters. Total length of each humerus was taken as distance between superior aspect of the head and most distal aspect of the trochlea. All measurements were taken to the nearest 0.1mm using Vernier caliper [7].

Foraminal index was calculated which can help clinicians to locate the nutrient artery.

The position of nutrient foramen in relation to zone was determined by calculating a Foraminal Index (FI) using the Hughes formula [10,11]:

FI= (DNF\TL) x 100

Where,

DNF - distance from proximal end of the bone to nutrient foramina.

TL - Total length of bone in millimeter.

The position of foramina was divided into three zones as follows:

Zone I: FI up to 33.33%, the foramen in proximal third of the bone.

Zone II: FI from 33.33% to 66.66%, the foramen in middle third of bone.

Zone III: FI above 66.66%, the foramen in distal third of bone.

STATISTICAL ANALYSIS

All measurements were recorded separately for right and left sided humeri using measuring scale, thread and vernier calliper. All the collected data were represented as mean and then analyzed with MS Excel 2007 software. The numerical data was statistically analyzed by calculating the percentage, mean and SD.

RESULTS

Number of foramina

The data of the distribution of number of the nutrient foramina (NF) recorded in the selected humeri is presented in Table 1. Of the total n = 122 subjects selected for the present study, n=68 were of right sided humeri and n = 54 were left sided.

The frequency of bone with single NF was present in n = 55 (80.88%) and n = 42 (77.78%) of right and left sided humeri respectively, two NF in n = 9 (13.24%) right and n = 8 (14.82%) left humeri and three NF in n = 2 (2.94%) right humeri and n = 2 (3.70%) in the left sided humeri whereas, no humeri had four NF. The NF was absent in n = 2 (2.94%) right humeri and n = 3 (3.70%) in left sided humeri. When

the right and left sided humeri were analyzed separately, the frequency of variation in the number of NF was almost similar.

The data in the table shows that number of NF in humeri was variable. Of the total n = 122 subjects, the percentage of bones having one NF is 79.51% (n = 97), two in 13.93% (n = 17) and three in 3.28% (n = 4) humeri and 3.28% (n = 4) were found with no foramina.

Location of foramina

The data of frequency of distribution of NF in respect to the surface of right (n = 68) and left (n = 54) sided humeri subjects studied is presented in Table 1.

In relation to surfaces, NF were located on antero-medial surface (AMS) in 82.36% (n = 56) in right sided humeri and 87.04% (n = 47) NF in left sided humeri, NF located on posterior surface (PS) was observed in 10.29% (n = 7) right sided humeri and 7.41% (n = 4) in left sided humeri and location of NF on the antero-lateral surface (ALS) was found in 7.35% (n = 5) and 5.55% (n = 3) in the right sided and left sided humeri respectively.

Of the total n = 122 subjects, majority (82.79%) of NF were located on the AMS of the shaft of humeri, followed by 10.65% on posterior surface (PS) and then 6.56% ALS of the shaft of humeri (Fig. 1).

Figure 1: Humerus showing location of nutrient foramen (NF).

Location of nutrient foramen in respect to zone

The distribution of NF in respect to the Zone (Fig 2) of the shaft of humerus observed in the present study humeri subjects is shown in Table 1. The incidence of NF present in upper one-third or Zone I of humeral shaft was found in n = 6 (8.83%) right sided humeri whereas, in n = 5 (9.26%) left sided humeri. Majority of the bones n = 58 (85.29%) and n = 46 (85.19%) had NF located in the middle one-third or Zone II of right and left sided humeri respectively. In n = 4 (5.88%), NF were present in lower one-third or Zone III of right sided humeri and n = 3 (5.55%) in Zone III of the left sided humeri.

The higher incidence of NF was recorded in n=104 (85.24%) in Zone II of the humeral shaft, followed by upper one-third or Zone I in n= 11 (9.02%) and least in lower one-third or zone III of n = 7 (5.74%).

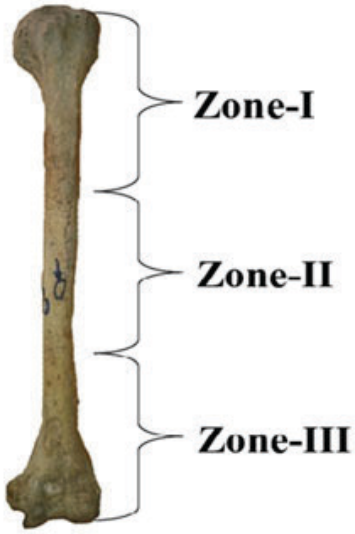

Figure 2: Humerus showing different zones.

Direction of foramina

In the present study, the direction of the NF showed no deviation from the normal anatomical feature even in a single case. It was observed that all n = 122 (100%) NF (Table 1) were directed distally downwards, towards the elbow joint or towards the lower end of humerus i.e. away from the growing end.

Table 1: Distribution of Number, Location and Direction of nutrient foramina in 122 humerus

Description of the nutrient foramina		Right humerus		Left humerus		Total	
		Frequency (n=68)	(%)	Frequency (n=54)	(%)	Frequency (n=58)	(%)
Number	0	2	2.94	2	3.70	4	3.28
	1	55	80.88	42	77.78	97	79.51
	2	9	13.24	8	14.82	17	13.93
	3	2	2.94	2	3.70	4	3.28

Description of the nutrient foramina		Right humerus		Left humerus		Total	
		Frequency (n=68)	(%)	Frequency (n=54)	(%)	Frequency (n=58)	(%)
Location (surface)	AMS	56	82.36	47	87.04	101	82.79
	PS	7	10.29	4	7.41	13	10.65
	ALS	5	7.35	3	5.55	8	5.55
Location (zone)	Zone I	6	8.83	5	9.26	11	9.02
	Zone II	58	85.29	46	85.19	104	85.24
	Zone III	4	5.88	3	5.55	7	5.74
Direction	Distal	68	100	54	100	122	100
	Proximal	0	0	0	0	0	0

AMS- antero-medial surface, PS- posterior surface, ALS- antero-lateral surface

The mean total length of the present study humerus bones and mean distance from proximal end of humerus to NF (right and left sided) and the Foraminal Index are presented in Table 2. The mean total length was found to be 269.32 mm in right and 268.17 mm in left sided humeri, the mean distance from proximal end of humeri to NF was 151.24 mm in right and 150.85 mm in left humeri and the Foraminal Index (FI) was recorded to be 53.46% for right humeri and 53.83% for left humeri. Therefore, mean and SD values of total mean length of humeral bones was 268.64±21.42 mm; and mean distance from proximal end of humeri to NF was 150.82 ± 16.46. The mean foraminal index was 54.25%.

Table 2: Mean values of statistical measurements of the humeri studied

Parameters	Right (mm) (n = 68)	Left (mm) (n = 54)	Total (n = 122)
	Mean ± SD	Mean ± SD	Mean ± SD
Mean Total Length	269.32 ± 18.43	268.17 ± 18.89	268.64±21.42
Distance from proximal end of the nutrient foramina	151.24 ± 15.87	150.85 ± 16.04	150.82±16.46
Foraminal Index (FI)	53.46%	53.83%	54.25%

DISCUSSION

The knowledge of variations of NF will be helpful for orthopaedic surgeons to avoid causing damage to the nutrient artery during an open reduction to improve fracture healing [5].

Inspite of giving optimal treatment, some fractures either heal slowly or fail to heal [9] and may be related to the severity of the injury, poor blood supply, age and nutritional status of the patient or other factors [12,13]. The arterial supply is very important factor for effective healing of a fractured bone [9,14,15].

Number of foramina

In the present study, majority (79.51%) humeri bones had single NF followed by double (13.93%) and then triple foramina in 3.28%, 3.28% humeri had no foramina similar to earlier reports [5,12,16]. Similar findings were observed by several authors. Forriol et al. [17] reported 75% bones had single foramina from a sample size 36 collected from Medical School of Alcala de Henares University, Yaseen et al. [18] 79% among 100 sample size and Ramya Sree et al. [19] 80% in Telangana region of sample size 218.

In contrast, several studies reported humeri with single foramen in only 58% [20] in Indian population. Similar findings were reported with incidence of 60.87% [22] in Nepalese population, 61.29% [23] in Haryana population, 63% [24] incidence among Gujarati population.

Whereas, many studies reported higher incidence of single NF compared to the present study results. Asharani and Ajay Ningaiah [26] in their study on Karnataka samples reported 87%, Kizilkanat et al.[2] reported in 88% bones, 88.5% by Peirere et al.[27] in Southern Brazil samples, 90% by Bhatnagar et al. [28] in Uttar Pradesh, India samples, 90% by Khan et al. [29], 90.62% by Rita Kumari and Renu Prasad [30], Laing [15] reported the incidence of single foramen in 93%, and Aashish and Sanjay [31] in 94.12% humeri.

The present study, 13.91% humeri bones had double NF similar to the findings of Longia et al. [5], Kizilkanat et al. [2], with their occurrence 13%, 13.91% and 22% humeral bones respectively. Similar findings were also observed by Halagatti and Rangasubhe [32] in 17.5%, Ukoha et al. [25] in 18% humeri bones.

The incidence of double NF was lesser in studies made by Bhatnagar et al. [28] in 7.14% and Solanke et al. [33] in only 4% bones.

In contrast to the present study results, higher incidence of double NF was reported by Mysorekar [20] in 42%, Shaheen [21] in 33.3%, Joshi et al. [24] in 33%, Mansur et al [22] reported in 28.85%, Carroll [9] in 28.16% and Kumar et al. [34] in 26% shaft of humeri.

Only few authors observed the presence of triple NF in accordance with the present study results recording triple NF in 3.28% humeral bones.

Kizilkanat et al. [2] reported triple NF in 7% humerus. Nearly similar results were reported by Kizilikant et al. [2] reported 6.93% in Turkey, Shaheen [21] in 6.7% among Saudi Arabia samples, Mansur et al. [22] in 6.32% of Nepal samples. Whereas, the findings of Bhatnagar et al. [28] were in 1.42%, and Halagatti and Rangasubhe [32] in 2%, Yaseen et al. [18] in 2% comparatively lesser than the finding observed in the present study (3.28%).

None of the humeri in our study had more than three NF while, Mysorekar [20] and Kizilkanat et al. [2] have observed humeri with even up to 4 NF.

In the present study, absence of NF was observed in 3.28% subjects. The results are almost in agreement with results reported by Vijayalakshmi et al. [16], Malukar and Joshi [7], Kizilkanat et al. [2], Asharani and Ajay Ningaiah [26]. Ankana et al. [35] reported absence of NF in 5% humeri. A higher incidence of absence of the nutrient foramina (26% of humeri) was reported by Ukoha et al. [25] study on 150 humeri in Nigerian population. Absence of NF in long bones is well known.

Location of nutrient foramen in respect to surface of humeri

The NF is located a little below its midpoint on the AMS close the medial border of humeri. However, location of the foramina may vary in position.

In the present study, 82.79% of the NF is situated on AMS of the humeri almost in accordance with the observations of Halagatti and Rangasubhe [32] showing 87% and Yaseen et al. [18] 88.5%.

In contrast to our results, higher incidence of NF located on the AMS of the humeral shaft were reported by Khan et al. [29] studies on 96% humeri of Pakistan population, Vikram Singh et al. [23] in 89.92%,

However, several authors reported lesser incidence of NF on the AMS of humeri. Gopalakrishna et al. [37] reported in 70.97%, Vinay et al. [38] in only 30.23%. These findings are supported by another study made by Chandrasekaran and Shanthi [12].

In the present study, majority (82.79%) of the NF were located on AMS of the humeral shaft, followed by PS (10.65%) and later ALS (5.55%), in accordance with results of Yaseen et al. [18] showing 11% and 3.5% on the PS and ALS respectively. In addition, the percentage of location of NF was recorded in 8.53% on PS and 1.55% on ALS, 2.67% on the PS and 1.33% on the ALS by Khan et al.[29] and Vikram Singh et al.[23] respectively. This finding is supported by the observations of NF located on the PS by Ukoha et al. [25] in humeri of Nigerian population with the incidence of 7.5% and Gopalakrishna et al. [37] 8.06%.

However, a study conducted by Anusha and Naidu [39] reported higher incidence (19%) of the presence of NF on PS than the present study results. Similarly, Forriol et al. [17] reported 15.55% of foramina in Spanish population and Kizilikant et al. [2] (18.1%) in Turkish population comparatively higher than the present study results.

Location of foramina in respect to zone of humeri

In the present study, majority of NF (85.24%) were found to be located on zone II (the middle one-third) of the shaft of humeri and are in correlation with the studies conducted by Halagatti and Rangasubhe [32] who reported the incidence in 84%, Aashish and Sanjay [18] in 86.11%, Asharani and Ajay Ningaiah [26] in 87% of NF in the middle one-third of the shaft of humeri.

Several authors in their studies reported high incidence of NF in zone II (middle one-third) of the shaft of the humeri similar to the present study results. Khan et al. [29] reported 96.20% in Pakistan cadavers, Mansur et al. [22] in 94.84%. While, Ukoha et al. [25] found 100% incidence in the humeri of Nigerian population, similar trend was recorded by Kumar et al. [34] with 100% incidence in Indian population which was much higher than the present study results.

In the present study, in 9.02% bones the NF were found to be located in zone I and 5.74% in zone III of the humeral shaft. Asharani and Ajay Ningaiah [26] observed 11% in zone II and none of them were located in Zone I Yaseen et al. [18]. Asharani and Ajay Ningaiah[26] reported NF were located in 22% in Zone I and 2% in the Zone III.

Direction of foramina

In the present study, the direction of the NF showed no deviation from the normal anatomical feature even in a single case. It was also observed that all NF were directed distally downwards, away from the growing end.

Several studies were conducted to observe the direction of NF in humerus to determine whether it follows the law of ossification or not.

The data in the present study, showed that the direction of all the NF of humeri was directed towards the lower end of humeri supported by many studies (Halagatti and Rangasubhe [32], Khan et al. [29], Gopalakrishna et al. [37], Kumar et al.

[34] which revealed that the direction of NF were constant and obeys the law of ossification [12,18,25,28,39]. Kumar et al. [34] reported that the direction of the NF present in all the humeri were directed away from the growing end of humeri except one which was directed towards the upper end. Similarly, Khan et al. [29] also found 98.67% of the NF were directed distally towards the lower end of humeri except one.

Berard [40] reported that the direction of NF of humeri was constant and the nutrient canal was slanted towards that end at which the epiphysis was first united with the shaft of humeri.

The direction of NF was directed horizontally before birth but as the growth proceeds, the direction of NF were directed from the growing end of the humeri [41].

Yaseen et al. [18] found deviation from normal anatomical characteristics in which NF were directed obliquely towards the elbow except one NF which was directed horizontally. The present study concluded that the entire NF present in the humeri was directed distally in agreement with many other studies [29,32,34], which clearly indicates that it follows the law of ossification.

Foraminal Index

In the present study, the mean total length of right and left sided humeri showed negligible variation recording 269.32 mm and 268.17 mm respectively (Table 3). Solanke, et al. [33] reported the mean length of right sided humeri as 28.53±1.78 cm and left sided humeri as 28.89 ±1.75cm. Mansur et al. [22] in their study on 253 adult humeri observed that the mean length of right side humeri as 27.05 cm and left sided as 26.99 cm, with foramen index 55.18%.

In the present study, the mean total length and standard deviation and the distance from proximal end of the NF (mm) was observed to be 268.64 ± 21.42 and 150.82 ± 16.46 respectively and the Forminal Index 54.25%.

Table 3: Mean values of statistical measurements of the humeri studied

Parameters	Right (mm) (n = 68)	Left (mm) (n = 54)	Total (n = 122)
	Mean	Mean	Mean ± SD
Mean Total Length	269.32	268.17	268.64±21.42
Distance from proximal end of the nutrient foramina	151.24	150.85	150.82±16.46
Foraminal Index (FI)	53.46%	53.83%	54.25%

Pereira et al. [27] reported mean foraminal index as 55.2% and Pramar et al. [42] also reported as 55.2% in accordance with the present study results.

Ukoha et al. [25] recorded mean foraminal index of humeri as 56.28% in Nigerian population and Muralimanju et al. [43] reported 57.6% among Indian population slightly higher in comparison to the present study results. However, Halagatti and Rangasubhe[32] reported 52.65% mean foraminal index for humeri, slightly lower than the other results.

CONCLUSION

The anatomical knowledge of number, location, and direction of nutrient foramina of humerus are very important for orthopedic surgeons during various surgical operations on the humerus like treatment of fracture, bone repair, bone grafting, micro-surgical bone transplantation, in many fractures and during extensive stripping of the periosteum so that they can minimize the damage to the nutrient artery of humeri. It helps to prevent intra-operative injuries in orthopedic, as well as in plastic and reconstructive surgery. The knowledge about the location and variations in the position of the nutrient foramina may also be helpful for appropriate placement of internal fixation devices during open or close procedures to limit the chances of delayed or non-union during fracture of the humeral shaft.

ACKNOWLEDGEMENT

The authors acknowledge the immense help received from the authors whose articles are cited and included in references of this manuscript. The author is also grateful to authors / editors / publishers of all those articles, journals and books from where the literature for this article has been reviewed and discussed.

REFERENCES

1. Standring S. Functional anatomy of the musculoskeletal system. Gray's Anatomy. 40th ed., Ch. 5. London: Elsevier Churchill Livingstone. 2008; 85-91.
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: 87-95.
3. Henderson RG. The position of the nutrient foramen in the growing tibia and femur of the rat. J Anat. 1978; 125(3): 593-599.
4. Krishna Garg. BD Chaurasia's Hand Book of General Anatomy. Blood supply of bones. 4th ed. 2011. CBS Publishers and Distributors Pvt. Ltd: 43-44.
5. Longia GS, Ajmani ML, Saxena SK, Thomas RJ. Study of diaphyseal nutrient foramina in human long bones. Acta Anat. 1980; 107: 399-406.
6. Sendemir E, Cimen A. Nutrient foramina in the shafts of lower limb long bones: situation and number. Surg Radiol Anat. 1991; 13: 105-8.

7. Malukar O, Joshi H. Diaphysial Nutrient Foramina In Long Bones And Miniature Long Bones. NJIRM. 2011; 2(2): 23-26.
8. Caroll SE. A study of nutrient foramina of the humeral diaphysis. J Bone Joint Surg. 1963; 45-3(1); 176-81.
9. Nagel A. The clinical significance of nutrient artery. Orthop Rev 1993; 22: 557-561.
10. Hughes H. The factors determining the direction of canal for the nutrient artery in the long bones of mammals and birds. Acta Anatomica. 1952; 15(3): 261-280.
11. Shulman SS. Observations of the nutrient foramina of the human radius and ulna. Anat. Rec. 1959; 134: 685-697.
12. Chandrasekaran S, Shanthi KC. A study of nuteient foramen of adult humerii. J clin and Diagn Res. 2013; 7(6): 975-977.
13. Bucholz RW, Brown CMC, Heckman JD, Tornetta P, Mcqueen MM, Ricci WM. Bone and joint healing. In: Buckwalter JA, Einhorn TA, Marsh JL, Gulotta L, Ranawat A, Lane J, editors, Rockwood and Green's Fractures in Adults. 7th edition. Philadelphia: Lippincott Williams and Wilkins. 2010; 1: 90.
14. 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): 2557–2564.
15. Laing PG. The Arterial supply of Adult Humerus, The J Bone and Joint Surg. 1956; 38A: 1105-1116.
16. Vijayalakshmi S. Bhojaraja, Sneha Guruprasad Kalthur, Antony S. Dsouza. Anatomical study of diaphyseal nutrient foramina in human adult humerus. Archiv Med and Health Sci. 2014; 2 (2): 165-169.
17. Forriol FC, Gomez LP, Gianonatti MA, Fernandez RV. A study of the nutrient foramina in human long bones. Surg Radiol Anat. 1987; 9: 251-255.
18. Yaseen S, Nitya W, Ravinder M. Morphological and topographical study of nutrient foramina in adult humerii. Int J Innov Res Sci Eng Technol. 2014; 3(4): 7-10.
19. Ramya Sree A, Udaya Kumar P, Kalpana T, Vinayaka Naik. Morphometric and morphological study of the nutrient foramina in dry human humerus bones of Telangana region. Int J Anat Res. 2019; 7: 6302 – 6306.
20. Mysorekar VR. Diaphysial nutrient foramina in human long bones. J Anat. 1967; 101: 813-822.
21. Shaheen SY. Diaphyseal nutrient foramina in human upper and lower limb long bones. A thesis submitted for the partial fulfillment of the requirement for the master degree in anatomy. 2009: 20-21.
22. 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.
23. Vikram S, Amit Kumar S, Prachi SA, Pawan M, A Study on Variations of Nutrient Foramen of Humerus and Its Clinical Significance. Int J Med Res Prof. 2018; 4(5); 255-258.
24. Joshi H, Doshi B, Malukar O. A study of the nutrient foramina of the humeral diaphysis. NJIRM. 2011; 2: 14-17.
25. 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): 304-308.
26. Asharani SK., Ajay Ningaiah. A study on the nutrient foramen of humerus. Int J Anat Res. 2016; 4 (3): 2706-2709.
27. Pereira GAM, Lopes PTC, Santos AMPV, Silveira FHS. Nutrient foramina in the upper and lower limb long bones: Morphometric study in bones of southern Brazilian adults. Int J Morph. 2011; 29(2): 514-520.
28. Bhatnagar S, Deshwal AK, Tripathi A. Nutrient foramina in the upper and lower limb long bones: A morphometric study in bones of western Uttar Pardesh. Int J Sci Res. 2014; 3(1): 301-303.
29. Khan AS, Shah Z, Inayat Q. Anatomical variations in diaphyseal nutrient foramina of humerus in cadavers from khyber pakhtunkhwa, Pakistan. Khyber Med Univ J. 2014; 6(1): 18-21.
30. Rita Kumari, Renu Prasad. Study on Nutrient Foramen of Humerus and Its Clinical Implication. IOSR J Dental Med Sci. 2019; 18 (5): 28-31.
31. Aashish JR, Sanjay RC. A study on variations of nutrient foramen of humerus. Int J Anat Res. 2019; 7: 6132 – 6137.
32. Halagatti MS, Rangasubhe P. A study of nutrient foramina in dry adult humerii of south Indian subjects. NJCA. 2011; 1(2): 76-80.
33. Solanke KS, Bhatnagar R, Pokhrel R. The number and position of nutrient foramina in humerus, radius, ulna of human dry bones of Indian origin with clinical correlation. *OA.* 2014;2(1):1-8.
34. Kumar S, Kathiresan K, Gowda MST, Nagalaxmi. Study of diaphyseal nutrient foramina in human long bones. Anat Karnataka. 2012; 6(2): 66-70.
35. Ankana S, Madhumita D, Soumya C, Sudipa B, Suranjali S. A study of nutrient foramen of dry adult humerus. Int J Anat Res. 2017; 5: 3722 – 3726.
36. Xinaris C, Benedetti V, Rizzo P, Abbate M, Corna D, Azzollini N, et al. In vivo maturation of functional renal organoids formed from embryonic cell suspensions. J Am Soc Nephrol. 2012; 23(11): 1857–68.
37. Gopalakrishna K, Sreekala MA, Rathna BS. A study on the incidence and direction of nutrient foramina in south Indian humeral diaphysis and their clinical importance. J Med Heal Sci. 2013; 3(1): 71-76.
38. Vinay G, Kumar AS. A study of nutrient foramina in long bones of upper limb. Anat Karnataka. 2011; 5(3): 53-56.
39. Anusha P, Naidu MP. A study on the nutrient foramina of long bones. Jour of Med Sci and Tech. 2013; 2(3): 150-157.
40. Berard A. Memoirs Sur Ie Rapport Qui Existe Entre La Direction Des Conduits Nourriciers Des Os Longs, Et I'ordre Suivant Lequelles Epiphyses Se Soudent Au Corps De I'os. Arch Gen Med Series. 1835; 27: 176-183.
41. Datta AK. Essentials of Human Osteology: General Consideration. 2nd ed. Kolkata. Current Books International 1997; 5.
42. Parmar AMB, Vaghela B, Shah K, Patel B, Tridevi B. Morphometric analysis of nutrient foramina in human typical long bones of upper limb. Natl J Integr Res Med. 2014; 5(5): 26-29.
43. Murlimanju BV, Prashanth KU, Prabhu LV, Saralaya VV, Pai MM, Rai 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.