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Original Article

Anatomy Section

Morphological Study of Nutrient Foramina in Long Bones of Upper Limb among North Gujarat Population

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ABSTRACT

Introduction: Main source of nutrition to long bone during growth and ossification is nutrient artery. Nutrient canal opens as nutrient foramen on the surface of shaft which conducts the nutrient artery and the peripheral nerves to bones. Nutrient artery provides more than 60-70% of blood supply to long bone, 30- 40% through periosteal, metaphyseal and epiphyseal blood vessels.

Aim: To determine number of nutrient foramina, its position on surface of shaft, size and direction of nutrient foramina either towards proximal end or distal end and find out foraminal index from the position of nutrient foramina.

Materials And Methods: A cross-sectional study was performed in 177 dry bones (60 humerus, 60 radius, 57 ulna) of upper limb, available at Anatomy Department, GMERS Medical College Himmatnagar, during September 2021. All bones were observed for number, position and direction of nutrient foramina. Size of foramen was measured by needles of different size. Mean Foraminal index was calculated for each long bone of upper limb by using Epi Info™ for windows, CDC, Atlanta, version 7.2.

Results: Majority of bones had single nutrient foramina, all foramina were directed towards the elbow joint. All nutrient foramina were on flexor surfaces of bone, except one bone (radius). Majority of nutrient foramina were situated on middle 3rd of the shaft. Size of nutrient foramen was range from 22 to 28 gauge of needle.

Conclusion: Information on nutrient foramina of long bones of upper limb will be useful in many orthopedic surgeries like microvascular bone grafting and many plastic reconstructive surgeries. During surgeries like fracture repair, bone graft or muscle graft care should be taken, not to damage these nutrient vessels to keep intact blood supply of bone.

Keywords: Bone graft, Foraminal index, Humerus, Nutrient artery, Radius, Ulna

INTRODUCTION

Nutrient artery enters the nutrient foramen, travels through nutrient canal to enter the medullary cavity and divides into ascending and descending branches. It supplies medulla and inner two third of cortex. Nutrient foramina are oblique in direction and it is directed away from the growing end [1]. In upper limb nutrient foramina are directed towards the elbow. Its position on shaft may vary depending upon growth of bone [2].

In Humerus bone of arm, nutrient foramina is situated on its anteromedial surface near its middle part of the shaft. Nutrient artery to humerus is branch of brachial artery [3]. Radius is lateral bone of forearm in which nutrient foramen is present on anterior surface of shaft, above its middlepart. Nutrient artery to radius is a branch of anterior interosseous artery. Ulna is medial bone of forearm in which nutrient foramen is present on anterior surface of shaft, above its middle part [4].

Nutrient artery is the main source of nutrition to shaft of long bone. So, its detailed knowledge is required during many orthopedic, plastic and reconstructive surgeries, like microvascular bone transfer to preserve bone [5,6]. Location of nutrient foramen is important for free vascularized graft of bone with endosteal and periosteal blood supply [7]. Sometimes additional nutrient arteries, passing through separate foramen is also present in long bones. Nutrient foramen is a site of stress fracture and shows specific pattern of edema related to stress fracture [8]. Detailed data on blood supply of long bone is required for development of new transplant and reconstructive surgeries of orthopedics [9].

In present study, all efforts were done to find out morphological anatomy of nutrient foramina of typical long bones of upper limb.

Aim of present study was to determine number of nutrient foramina, its position on surface of shaft, size and direction of foramina, either towards proximal end or distal end.

MATERIALS AND METHODS

A cross-sectional study was performed in 177 dry bones of upper limb (60 humerus, 60 radius, 57 ulna) presented at Anatomy Department, GMERS Medical College Himmatnagar, Gujarat,India, during september 2021. Bones were studied irrespective of age and sex of bones. Laterality of bone was identified.

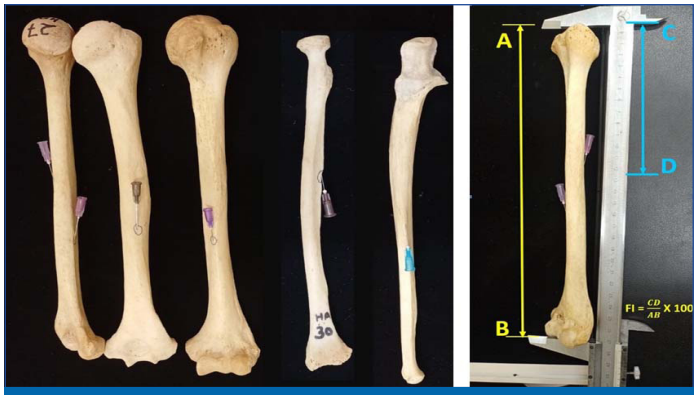
Inclusion criteria: All intact, adult human long bones of upper limb (humerus, radius and ulna) were included in present study.

Exclusion criteria: Bone with any gross asymmetry or proximal/distal broken ends or with incomplete fusion of fracture shaft was excluded from study.

Study Procedure

Bones were analysed for number, position and direction of nutrient foramina by naked eye. Nutrient foramina were identified with a groove leading to canal and raised ridge around it [10].

- Size of foramen was measured by hypodermic needle of different size like 21, 22, 23, 24, 26 and 28 gauge [Table/Fig-1]. Foramen with larger lumen was called dominant foramen and with smaller lumen was called accessory foramen.
- The direction of nutrient canal was observed with direction of needle when it inserted to check the size of foramen.
- The length of bone and distance of nutrient foramen from proximal end of bone was measured by vernier caliper [Table/Fig-2].



[Table/Fig-1]: Measurement of size of nutrient foramen.
[Table/Fig-2]: Showing measurement of various parameters for foraminal index.
AB: Length of bone; CD: Distance of nutrient foramen from the proximal end; FI: Foramen index. (Images from left to right).

- The foraminal index was calculated as per below mentioned formula and mean foraminal index of each long bone has been calculated [11].

$$\text{Foraminal Index (F1)} = \frac{\text{Distance of nutrient foramen from proximal end to bone}}{\text{Total length of bone}} \times 100$$

According to foraminal index, position of nutrient foramina were classified in to three types-

- **Type 1:** Foraminal index <33.33 %, nutrient foramen was on proximal third of the shaft.
- **Type 2:** Foraminal index between 33.33 to 66.66%, nutrient foramen was on the middle third of the shaft.
- **Type 3:** Foraminal index above 66.66%, nutrient foramen was on the distal third of the shaft [10].

STATISTICAL ANALYSIS

All measurements were recorded separately for humeri, radii and ulna using vernier calliper. Analysis of collected data was done to calculate foraminal index of each bone and find out mean foraminal index of each bone by using Epi Info™ for windows, CDC, Atlanta, version 7.2.

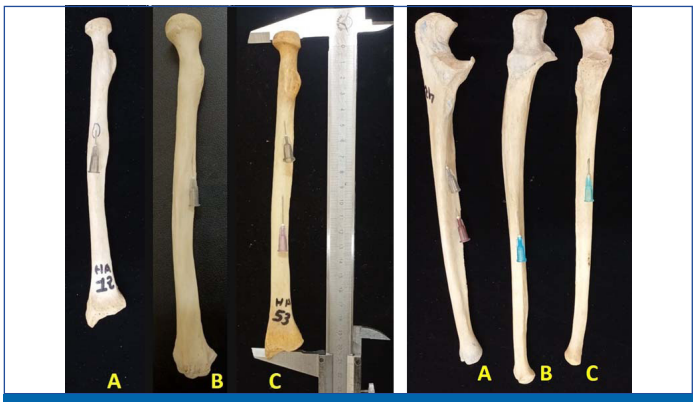
RESULTS

Humerus: Mean length of humerus was 28.84 cm in present study. All nutrient foramina were directed downward and following the rule for nutrient foramina, direction opposite to growing end. All nutrient foramina were located on flexor surfaces and near borders of bone. 82.75% (n=48) of nutrient foramina were situated on middle 3rd of the shaft, while 17.24% (n=10) on distal 3rd of the shaft [Table/Fig-3].

[Table/Fig-3]: Position of nutrient foramina in humerus.
A. Two nutrient foramina (both 24 gauge size) B. and C. Nutrient foramen on middle 1/3rd of shaft with (B 22 and C 24 gauge size)

Radius: Mean length of radius in present study was 22.95 cm. All nutrient foramina were directed upward, opposite to growing end. All nutrient foramina were situated on flexor surface and border of bone except in 1 radius bone, where nutrient foramen was present on posterior surface of shaft. 83.67 % (n=41) of nutrient foramina were on middle part of shaft, while 16.33 % (n=8) were on proximal part of the shaft of radius [Table/Fig-4].

Ulna: Mean length of ulna in present study was 24.54 cm. All nutrient foramina were directed upward, opposite to growing end. 88% (n=44) of foramina were on middle part of shaft while 12% (n=6) were on proximal 3rd of shaft of ulna [Table/Fig-5].



[Table/Fig-4]: Position of nutrient foramina in Radius.
A. Nutrient foramen on Proximal 1/3rd (on anterior surface), B. Nutrient foramen on middle 1/3rd (on Posterior surface); C. Two nutrient Foramina on anterior surface, one in proximal 1/3rd and other in middle 1/3rd
[Table/Fig-5]: Position of nutrient foramina in Ulna .
A. Two nutrient Foramina on anterior surface, B. Nutrient foramen on middle 1/3rd; C. Nutrient foramen on Proximal 1/3rd (Images from left to right)

[Table/Fig-6-8] give details of number of nutrient foramina in long bone of upper limb, its average size and mean foraminal index respectively. [Table/Fig-9,10] give details of position of nutrient foramen on bone surface or border.

Number of nutrient foramina	Humerus (n=60)	Radius (n=60)	Ulna (n=57)
0*	7 (11.66%)	12 (20%)	9 (15.78%)
1	48 (80%)	47 (78.33%)	46 (80.70%)
2	5 (8.33%)	1 (01.67%)	2 (3.5%)

[Table/Fig-6]: Number of nutrient foramina.
*0: Nutrient foramen was obliterated and nutrition to bone was provided by periosteal blood vessels.

Size of nutrient foramina (gauge of needle)	Humerus (TNF=58)	Radius (TNF=49)	Ulna (TNF=50)
22	8 (13.79%)	3 (6.12%)	12 (24%)
24	26 (44.83%)	14 (28.57%)	18 (36%)
26	4 (6.89%)	8 (16.33%)	3 (6%)
28	20 (34.48%)	24 (48.98%)	17 (34%)

[Table/Fig-7]: Size of nutrient foramina.
TNF: Total nutrient foramina of respective bone

Position of nutrient foramina according to foraminal index	Humerus (TNF=58)	Radius (TNF=49)	Ulna (TNF=50)
Type 1 (0 to 33.33%)	0	08 (16.33%)	06 (12%)
Type 2 (33.33 to 66.66%)	48 (82.75%)	41 (83.67%)	44 (88%)
Type 3 (66.67 to 100%)	10 (17.24%)	0	0
Range of foraminal index	44.59-74.90	25.26-53.44	30.76-50.40
Mean foraminal index	61.23	38.83	38.12

[Table/Fig-8]: Position of nutrient foramina according to foraminal index.
TNF=Total Nutrient foramina of respective bone

Surface / border	Humerus (TNF = 58)
Anterior border	04
Anterolateral surface	04
Anteromedial surface	40
Medial border	10

[Table/Fig-9]: Position of nutrient foramina on humerus .
TNF=Total Nutrient foramina of respective bone

Surface/Border	Radius (TNF=49)	Ulna (TNF=50)
Anterior border	03	07
Interosseous border	02	01
Anterior surface	43	42
Posterior surface	01	0

[Table/Fig-10]: Position of nutrient foramina on radius and ulna.
TNF: Total Nutrient foramina of respective bone

DISCUSSION

Nutrient foramen leading to nutrient canal, through which nutrient vessels pass to the medullary cavity of a long bone and supplies inner 1/3rd of cortex and medullary cavity. Sometimes accessory nutrient foramina are present, which supplies the cortex and medulla of shaft but these foramina are of smaller in size. During surgeries like fracture repair, bone graft or muscle graft care should be taken not to damage these nutrient vessels to keep intact blood supply of bone [10].

Mansur DI et al., study (2016) [5] showed that out of total 253 humerus, 154 (60.86%) had single nutrient foramina, 73 (28.85%) humerus showing double nutrient foramina; while they also found one humerus with 4 nutrient foramina. Murlimanju BV et al., (2011) [6] study found that out of 96 humerus, 93.8% humeri had single nutrient foramina, 3.1% humeri had double nutrient foramina and absent nutrient foramina had found in 3.1% of humeri. Chakka S and Lattupalli H (2020) [12] found that out of 50 humerus, 36 (72%) had single nutrient foramina while 12 (24%) had double nutrient foramina. In Xue Z et al., study (2016) [13], 84.21% humerus have single nutrient foramina, 13.16% have double nutrient foramina, while 2.63% have no nutrient foramina. In present study 48 (80%) of humeri had single nutrient foramen, 5 (8.33%) have double nutrient foramina which coincide with other studies. While found (11.66% 7) humeri without nutrient foramen, suggesting that its nutrients foramen was obliterated and may supplied by periosteal vessels [Table/Fig-11] [5,6,9,12-25].

Mysorekar VR (1967) [9] study showed 93% of radii with single nutrient foramen, 2.22% of radii without nutrient foramina and 4.44% of radii have double nutrient foramina. Chakka S and Lattupalli H (2020) [12] found that out of 50 radius, 3 (6%) radius showed double nutrient foramina while in one radius with no nutrient foramina found. In present study, 78.33% of radius shows single nutrient foramen, 20% of radius has no nutrient foramen while 1.67 % has double nutrient foramina [Table/Fig-11] [5,6,9,12-25].

Sr. no.	Author's Name, Year & Place	Number of nutrient foramina in Humerus	Number of nutrient foramina in Radius	Number of nutrient foramina in Ulna
1	Mysorekar VR, [9], 1967, Poona	0-00	0-04	0-02
		1-104	1-168	1-168
		2-68	2-08	2-10
		3-05		
		4-02		
		(n=179)	(n=180)	(n=180)
2	Murlimanju BV et al., [6], 2011, Manipal, India.	0-03	0-03	0-00
		1-90	1-68	1-75
		2-03	2-01	2-00
		(n=96)	(n=72)	(n=75)
3	Reddy GRMK et al., [14], 2016, Kadapa, Andhra Pradesh	NA	0-00	0-00
			1-52	1-50
			2-02	2-00
			(n=54)	(n=50)
4	Asharani SK and Ajay Ningaiah, [15], 2016, Karnataka	0-02	NA	NA
		1-104		
		2-14		
		(n=120)		
5	Mansur DI et al., study [5], 2016, Kathmandu, Nepal.	0-05	NA	NA
		1-154		
		2-73		
		3-16		
		4-05		
		(n=253)		
6	Xue Z et al., study [13], 2016, China	0-01	NA	NA
		1-32		
		2-05		
		(n=38)		
7	Veeramuthu M et al., [16], 2017, Tamil Nadu	0-01	0-00	0-01
		1-46	1-57	1-57
		2-08	2-02	2-01
		(n=55)	(n=59)	(n=59)
8	Spatika A et al., [17], 2017, Karnataka	NA	0-00	0-00
			1-62	1-66
			2-07	2-18
			(n=69)	(n=84)
9	Pankaj AK et al., [18], 2017, Uttar Pradesh	0-19	NA	NA
		1-283		
		2-47		
		3-01		
		(n=350)		
10	Naveen KB et al., [19], 2018, Telangana	NA	0-07	NA
			1-167	
			2-05	
			(n= 179)	
11	Joshi P et al., [20], 2018, Rajasthan	0-03	0-02	0-00
		1-46	1-48	1-48
		2-01	2-00	2-02
		(n=50)	(n=50)	(n=50)
12	Sukumar CD [21] 2019, Andhra Pradesh	0-4	NA	NA
		1-97		
		2-17		
		3-4		
		(n=122)		
13	Savithri K et al., [22], 2019, Coimbatore, Tamil Nadu	0-04	NA	NA
		1-55		
		2-21		
		3-03		
		4-02		
		(n=85)		
14	Challa P et al., [23], 2019, Guntur, Andhra Pradesh	0-00	0-00	0-00
		1-39	1-50	1-49
		2-11	2-00	2-01
		(n=50)	(n=50)	(n=50)
15	Chakka S and Lattupalli H. [12], 2020, Andhra Pradesh	0-02	0-01	0-00
		1-36	1-46	1-50
		2 – 12	2-03	2-00
		(n=50)	(n=50)	(n=50)
16	Sintakala C et al., [24], 2020, Nepal	0-4	NA	NA
		1-143		
		2-44		
		3-9		
		(n=200)		

17	Haris M et al., [25] 2021, Pakistan	0-00	NA	NA
		1-33		
		2-14		
		3-03		
		(n=50)		
18	Present study 2021, Gujarat.	0-07	0-12	0-09
		1-48	1-47	1-46
		2-05	2-01	2-02
		(n=60)	(n=60)	(n=57)

[Table/Fig-11]: Comparison of various studies in regards to numbers of nutrient foramina [5,6,9,12-25].

Mysorekar VR (1967) [9] study showed 93.33% of ulna with single nutrient foramen, 1.11% of ulna without nutrient foramina and 5.55% of ulna had double nutrient foramina. In present study 80.70% of ulna have single nutrient foramina, 15.78% had no nutrient foramina while 3.5% had double nutrient foramina. Comparison between similar studies has been done in [Table/Fig-11] [5,6,9,12-25].

Mean foraminal index for humerus was 56.28±4.90 in Ukoha U et al., (2013) study [11], 57.6 in Murlimanju BV et al., (2011) study [6] and 55.2 in Pereira et al., study [26]. 86.43% of the nutrient foramen was located in the middle 1/3rd of the shaft of humerus bone and in 13.57% of the nutrient foramen was located in the lower 1/3rd of the bone in Chandrasekaran S and Shanthi KC study [27]. Mean Foraminal Index for humerus was 61.23 in present studies. Most of the humeral nutrient foramina were on middle 1/3rd of shaft (82.75%) while, rest of the foramina were on distal 1/3rd of shaft. All foramina were directed downward, towards the elbow which correlates with other studies [Table/Fig-12] [6,11,14,16,19-21,24,26,28].

Sr. No.	Author's Name, Year & Place	Mean FI of Humerus	Mean FI of Radius	Mean FI of Ulna
1	Pereira et al., [26] 2011, Brazil	55.2 (n=174)	35.7 (n=157)	37.9 (n=146)
2	Murlimanju BV et al., [6] 2011, Manipal, India	57.6 (n=96)	34.4 (n=72)	34.4 (n=75)
3	Ukoha U et al., [11] 2013, Nigeria	56.28±4.90 (n=150)	33.74±4.94 (n=50)	36.70±4.56 (n=50)
4	Reddy GRMK et al., [14] 2016, Kadapa, Andhrapradesh	-	33.2 (n=54)	35.2 (n=50)
5	Veeramuthu. M et al., [16] 2017, Tamilnadu	58.95±5.63 (n=55)	33.78±4.64 (n=59)	36.39±5.61 (n=59)
6	Joshi P and Mathur S. [20], 2018, Rajasthan	57.26 (n=50)	35.48 (n=50)	34.53 (n=50)
7	Naveen Kumar. B et al., [19], 2018, Telangana	-	34.86±4.7 (n=179)	-
8	Akbari VJ et al., [28] 2019, Saurashtra-Gujarat.	-	36.14±7.11 (n=63)	-
9	Sukumar CD [21] 2019, Andhrapradesh	54.25% (n=122)	-	-
10	Sintakala C and Manandhar M, [24] 2020, Nepal	56.18 (n=200)	-	-
11	Present study, 2021, Gujarat, India	61.23	38.83	38.12

[Table/Fig-12]: Comparison of various studies in regards to mean foraminal index [6,11,14,16,19-21,24,26,28].
FI: Foraminal index

Mean FI was 43.4 for both radius and ulna in Murlimanju BV et al., (2011) [6] study; 35.7 for radius and 37.9 for ulna in Pereira et al., (2011) (26) study, while Mean FI for radius was 38.83, and for ulna it was 38.12 in present study which correlates with previous studies. Most of the radius and ulna, nutrient foramina were on middle 1/3rd of shaft, 83.67% and 88%, respectively while, rest of the foramina were on proximal 1/3rd of shaft. All foramina were directed upward, towards the elbow joint [Table/Fig-12] [6,11,14,16,19-21,24,26,28].

Kizilkanat E et al., study (2007) said that nutrient foramina of long bone were located on flexor surfaces of bone near the attachment of muscles [29]. In present study all nutrient foramina were situated on flexor surface of bone except one foramen in radius, which was situated on posterior surface of radius which coincides coincide with previous studies [9,12,19,26].

Limitation(s)

Present study includes only adult dry bones of upper limb only, further research on child bones also to be conducted and compared with adult bones to show migration and changes in size of nutrient foramina of bones of upper limb.

CONCLUSION(S)

Majority of long bones of upper limb have single nutrient foramina and all nutrient foramina were directed towards the elbow joint, opposite the direction of growing end. All nutrient foramina were located on flexor surfaces of bone. Majority of nutrient foramina were situated on middle third of shaft of long bone. But in few, humerus foramina were also found on distal third of shaft and in some of radius and ulna foramina were situated on proximal third of shaft. This information on nutrient foramina of long bones of upper limb will be useful to orthopedic surgeons while performing various fracture repair surgeries or microvascular bone grafting.

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