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The Diaphyseal nutrient foramina architecture - a study on the human upper and lower limb long bones

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Abstract: *The nutrient foramina are cavities that conduct the nutrient arteries and the peripheral nerves on the shaft of long bones. Long bones receive most of the interosseous blood supply from the nutrient arteries, and sometimes through the periosteal vessels. Nutrient arteries play an important role in nutrition and growth of the bones particularly during its growth period in the embryo and fetus as well as during early phases of ossification. The present study was conducted in the department of Anatomy, MNR Medical college, Sangareddy, Medak, Andhra Pradesh and Govt. Medical College, Aurangabad, Maharashtra. A study group comprised of 1320 (840male, 480 female) long bones of upper and lower limbs of known age and sex from the bone library. The number, location, direction, position and also whether the nutrient foramina obey the general rule that is directed away from the growing end of long bone is determined in this study. Distance of nutrient foramina from either ends of long bones are more in males than females. Single nutrient foramen is common in females whereas multiple nutrient foramena in males. Femur showed highest number of nutrient foramena in 2nd segment in males and females only 1% shows multiple nutrient foramens in second segment. Two nutrient foramens were found in 68% of femur, 14% of tibia, 20% of fibula and only 10% of Humerus while it is less in females.*

Keywords: *Nutrient Foramen, Diaphysis, Long Bone, Segments of long bone.*

I. Introduction

The nutrient foramen is defined as the largest of the foramen present on the shaft of long bone allowing nutrient artery to enter the bone, the role of which is important in providing nutrition and growth of long bones [1].

Their direction follows a general adult rule "towards the knee and away from elbow I flee". The nutrient foramen is distinguished from any other foramen by the presence of distinct vascular groove outside the nutrient foramen. The direction of nutrient canal is important to denote the growing end of a bone [2, 3].

The external opening of the nutrient canal, usually referred to as the nutrient foramen, has a particular position for each bone [4]. Longia GS *et al.* [5] observed that the position of nutrient foramina was on the flexor aspect in their human long bone specimens. It is generally agreed that the vessels which occupy the nutrient foramen are derived from those that took part in the initial invasion of the ossifying cartilage, so that the nutrient foramen was at the site of original centre of ossification [4, 5].

Study of relative relationship between the length of bone and distance of nutrient foramen from either ends is useful in calculating the length of a long bone from a given fragment, which is important in medico-legal and anthropological work. From the length of the long bones height of an individual can be reconstructed [5].

An understanding of the location and the number of the nutrient foramina in long bones is therefore important in orthopedic surgical procedures such as joint replacement therapy, fracture repair bone grafts and vascularized bone microsurgery as well as medico legal cases.

In free vascular bone grafting, the nutrient blood supply is extremely important and must be preserved to promote fracture repair, a good blood supply being necessary for osteoblast and osteocyte cell survival, as well as facilitating graft healing in the recipient [5, 6].

Large number of studies has been made to determine the number, position and direction of nutrient foramen and also their distance from the ends of the long bones. Most of these studies have compared the data of the right and left but no attempt was made to find out if there is any sex difference in it.

The present study has been under taken with the aim of carrying out extensive study of the nutrient foramen in human long bones of both sexes. The number, position, direction, its distance from the ends and the diameter of shaft at the site of nutrient foramen is being studied, analyzed and discussed.

II. Materials and Methods

For the present study a total 1320 long bones of known age and sex belonging to the skeletal collection of the department of anatomy, MNR Medical College, Sangareddy, Medak, Andhra Pradesh and Govt. medical college, Aurangabad, Maharashtra taken for the study. Male and females bones were studied separately.

Exclusion criteria: bones with deformities and fractured bones are excluded from this study

Following long bones were taken for the present study

1. Femur
2. Tibia
3. Fibula
4. Humerus
5. Radius
6. Ulna

Following parameters were studied in male and females and tabulated separately for the present study:

1. Total length: length of each long bone was measured with Osteometric board.
2. Number of nutrient foramen: with magnifying lens.
3. Direction and obliquity of nutrient foramen
4. Distance of nutrient foramen from upper end: measured with Vernier calipers.
5. Distance of nutrient foramen from lower end: measured with Vernier calipers.
6. Antero-posterior diameter of the shaft: measured with Vernier calipers.
7. Medio-lateral diameter of the shaft: measured with Vernier calipers.
8. Position of nutrient foramen according to the segments: To locate the exact position of nutrient foramen and to study its direction, the shaft of each long bone was divided in to various segments. First total length of each long bone was measured by Osteometric board then it was divided into various equal segments by Vernier calipers. For the sake of convenience Humerus and femur were divided in to 6 segments while other bones viz. radius, ulna, tibia, fibula were divided in to 3 segments. In each segment the nutrient foramen was searched with hand lens (Fig 1&2).

Instruments used for the study:

1. Hand lens: used to locate nutrient foramina.
2. Osteometric board: used to measure the length of long bones.
3. Vernier calipers: used to measure diameter of the long bones.

Male and female long bones were studied separately. At the first instance these measurements were tabulated and statistically analyzed.

III. Result

Table 1: showing mean values of various parameters of long bones in male and female

Bones	**Total length**		**Distance from upper end to N.F**		**Distance from lower end to N.F**		**A-P diameter of N.F**		**Medio-lateral diameter at N.F**	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Humerus	31.2	28.66	18.74	17	12.58	11.99	1.86	1.62	1.71	1.46
Radius	24.59	22.3	9.44	8.27	15.95	14.15	1.12	0.98	1.68	1.22
Ulna	26.78	24.4	10.61	8.92	16.84	15.70	1.27	1.12	1.41	1.28
Femur	43.43	40.32	13.7	12.74	29.8	27.8	2.56	2.23	2.51	2.31
Tibia	37.7	35.1	12.21	11.73	25.62	23.44	2.88	2.73	2.08	1.94
Fibula	36.2	33.8	15.01	14.70	20.10	18.36	1.27	0.99	0.99	1.30

Table .1 shows maximum length in femur 43.43cm in males the least length was in radius in 24.59cm. In females femur showed 40.32cm while radius showed 22.30cm. This sexual variation is statistically significant.

Except in tibia and fibula and in other long bones the distance of nutrient foramina from upper end is found to be significant.

Highest value of distance of nutrient foramina from lower end is reported in femur 29.8 cm in males and females 27.8 cm. least values were seen in Humerus (12.58 in males and in females 11.99cm). While ulna and femur did not show significant difference in either sex. Medio-lateral and antero-posterior diameter at nutrient foramina showed higher values in males than in females except in tibia.

Table 2: showing percentage of incidence of nutrient foramina in long bones

Bones	**One N.F (%)**		**Two N.F (%)**		**Three N.F (%)**	
	Male	Female	Male	Female	Male	Female
Humerus	90	98	10	2	0	0
Radius	100	100	0	0	0	0
Ulna	100	100	0	0	0	0
Femur	25	80	60	19	15	1
Tibia	86	96	14	0	0	0
Fibula	80	95	20	5	0	0

Table 2 shows that number of nutrient foramina in long bones were variable. Most of the bones having only one nutrient foramen, but the femur showed presence of 3 nutrient foramina (males 15%, females1%). Presence of two nutrient foramina were observed in Humerus (males10%, females2%), in fibula (males 20%, females5%).

Table 3: showing the position of nutrient foramina in each segment of long bones

Bones	**1st segment**		**2nd segment**		**3rd segment**		**4th segment**		**5th segment**		**6thsegment**	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	female
Humerus	-	-	-	-	24	8	112	72	18	4	-	-
Radius	130	80	10	-	-	-	-	-	-	-	-	-
Ulna	70	75	72	5	-	-	-	-	-	-	-	-
Femur	-	-	152	75	24	-	90	24	-	-	-	-
Tibia	147	80	-	-	-	-	-	-	-	-	-	-
Fibula	-	4	168	66	-	14	-	-	-	-	-	-

For locating the position of nutrient foramina the bones were divided in to 3 segments except femur and Humerus which were divided in to 6 segments (Fig1 & 2).

In Humerus nutrient foramina was found in 4th segment in males and females (112 and 72). In radius nutrient foramina was found in 1st segment in males130 and in females 80. In ulna nutrient foramina is equally distributed in 1st and 2nd segment in males, while in female it is found more in 1st segment than 2nd segment (table3).

In femur 2nd and 4th segment showed higher number of nutrient foramina in both sexes (males 152/90, females 75/24) respectively (table3).

In tibia nutrient foramina is constant in position in 1st segment on vertical line (147 in males and 80 in females).

Fibula showed more number of nutrient foramina in 2nd segment of both sexes (male168 and female 66) (table3).

Fig. 1. Showing Segments of shafts of Humerus, Radius and ulna, and the occurence of nutrient foramina.

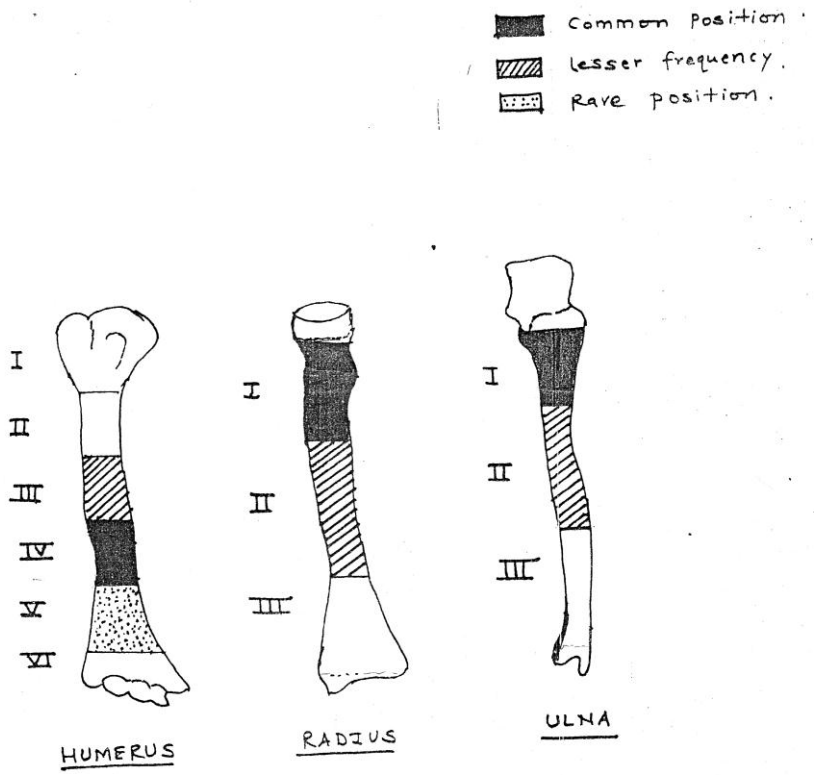
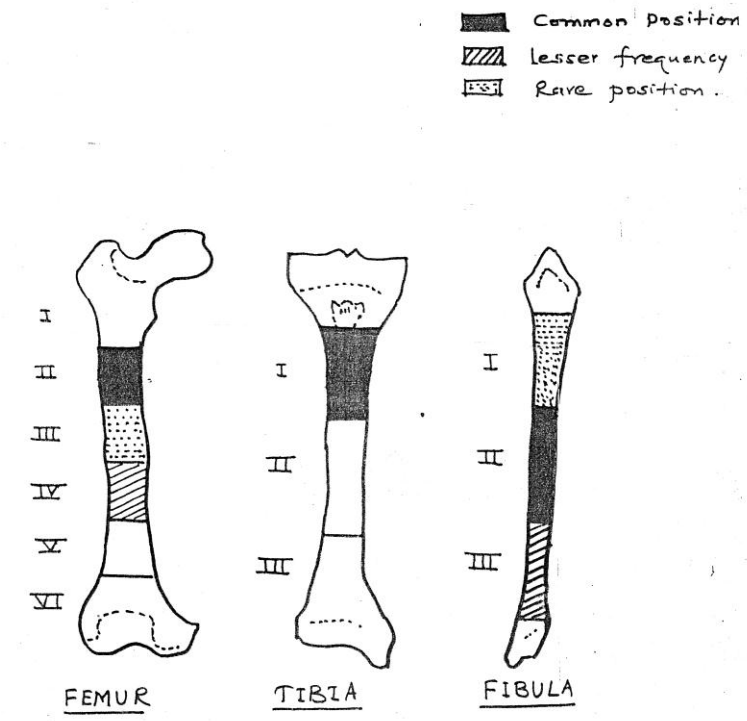


Fig. 2. Showing Segments of shafts of Femur, Tibia and Fibula and the occurence of nutrient foramina.



IV. Discussion

In embryonic period all the nutrient arteries course caudally. This is true in hemodynamic point of view to force the blood from cephalic to caudal side. This agrees with adult rules "towards the knee and away from elbow". This is said to be due to unequal growth of the ends of the long bones.

The arrangement of diaphyseal nutrient foramen in long bones usually follows a definite pattern. Position is constant and seen on flexor surfaces.

The direction of nutrient foramina in human long bones is directed away from the growing end. This is due to one end of long bone is growing faster than the other end. In many tetra pods**,** there is variation in the directions of nutrient foramina, but in mammals and birds Hughes pointed out that Anomalous canal are frequent, especially in femur [10].

Location of nutrient foramen in different segments of long bones:

a) Humerus: Mysorkar reported the nutrient foramen in Humerus along the medial border in 4^{th} segment. The present study correlates with this study (Fig.1).
b) Radius: Mysorkar reported nutrient foramen in 2^{nd} segment, while in present study nutrient foramen is found in 1^{st} segment in both sex (Fig.1).
c) Ulna: the nutrient foramina were having equal distribution in 1^{st}, 2^{nd} segments, anterior surface and anterior border of the shaft which correlates with the findings of Mysorkar (Fig.1).
d) Femur: In femur the position of the nutrient foramina showed much variability. Mysorkar quoted higher number of nutrient foramena in 3^{rd} and 4^{th} segment while in present study it is prevalent in 2^{nd}, 3^{rd} and 4^{th} segments. This difference may be due to geographical variation (Fig.2).
e) Tibia: tibia showed most consistency in position of nutrient foramina. It was constantly present in the 1^{st} segment of the shaft and more commonly on vertical line and less commonly lateral to the vertical line. The present study correlates with the study of Mysorkar (Fig.2).
f) Fibula: fibula showed presence of nutrient foramina in 2^{nd} segment and on the medial crest of the bone. The present study correlates with study of Mysorkar (Fig.2).

Direction of nutrient canal:

Direction and obliquity of nutrient canal shows the general pattern i.e. towards the knee and away from the elbow. All the upwardly directed foramina were situated much below the middle of the shaft of the bone. There was no change in the obliquity of the canal when the foramina were situated in the centre of the bone compared to when they were nearer the ends. The foramina in the tibia were most oblique ones, so much so that they were practically vertical. In femur, foramina were least oblique as compared to other bones.

1. Total length of bone is more in males than in females in all the long bones studied. Femur has the maximum length of 43.43cm in males and 40.23 in females. Whereas the radius has minimum of the length i.e. male 24.59cm and female 22.30 cm.
2. The distance of the nutrient foramena from either ends of the bones are more in males than females in all the bones. In femur in males the distance from the upper end to the nutrient foramena is 21.75 cm. in females 19.89cm. The distance of nutrient foramen from the lower end in case of males is 21.68 cm while in females it is 20.48cm.
3. Antero-posterior diameter of the shaft at the site of nutrient foramen is more in all male bones than the females.
4. The Medio-lateral diameter of the shaft at the nutrient foramen is more in all male long bones than in females.
5. Single nutrient foramen is common in females whereas multiple numbers of foramina are common in males.

Percentage of nutrient foramen in long bones:

1. Femur in males shows highest incidence of multiple foramina (15%). These are present on the medial side of linea aspera. The location is either in 2^{nd} segment (58.5%) or in 4^{th} segment (32.8%). In females the femur shows only 1% of three nutrient foramina. The site for the occurrence of the nutrient foramen is on the linea aspera in 2^{nd} segment (74%) and in 4^{th} segment (26.1%).
2. The incidence of occurrence of 2 nutrient foramina is 10% in Humerus, 60% in femur, 14% in tibia and 20% in fibula of male bones. While it is comparatively less in females.
3. The position of nutrient foramen in Humerus is confined to the 4^{th} segment in either sexes (males 68.6% and females84%). It was present on the medial border and antero-medial surface in either sex.
4. Radius shows nutrient foramen in 1^{st} segment and on anterior border (males 92% and females 99%).

5. Ulna shows nutrient foramen in 1st segment and on anterior surface in females (95%), while in males it is present in 2nd segment and anterior border (51%).
6. Tibia shows constant position of nutrient foramen on the vertical line in 1st segment in either sex. In males 75% of foramina were found on a vertical line but in females the incidence of foramina on vertical line is 56%.
7. Fibula shows common position of nutrient foramen in 2nd segment and on the medial crest of the bone in either sex.

Comparison of present study with the previous study:

1. Chatrapati and Mishra found the total length of Humerus as 31.4cm which correlates with present study i.e.30.43cm.Distance of nutrient foramen from upper end is 18.14cm and that of lower end is 13.44cm similar findings were found in present study i.e. 17.80 cm and 12.24 cm respectively.
2. In radius distance of nutrient foramen from lower end is 15.61 cm (Chatrapati) and present study 10.05 cm.
3. In ulna and tibia the length of the bones and distance of nutrient foramen from the ends showed equal values in present study with the study of Chatrapati and Mishra.

V. Conclusion

Distance of nutrient foramena from either ends of long bones are more in males than females. Single nutrient foramen if common in females whereas multiple nutrient foramena in males. Femur showed highest number of nutrient foramena in 2nd segment in males and females only 1% shows multiple nutrient foramens in second segment. Two nutrient foramens were found in 68% of femur, 14% of tibia, 20% of fibula and only 10% of Humerus while it is less in females. In Humerus nutrient foramena located in 4th segment in both sexes. Tibia shows constant position of nutrient foramen in 1st segment and the nutrient canal is most oblique one and obliquity is more when nutrient foramena is situated towards the ends.

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