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Original Research Article

Variations in nutrient foramen in the long bones of lower limb

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A R T I C L E I N F O

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A B S T R A C T

Background: Morphology and morphometry of nutrient foramen of bones vary from country to country and from place to place.
Objective: Objective was to study the number, position, location, directions, distance of nutrient foramen from the proximal end of femur, tibia and fibula in eastern Indian region.
Materials and Methods: In a descriptive study, 393 bilateral lower limb long bones (138 femur, 132 tibia & 123 fibulae) were studied.
Results: Total nutrient foramen calculated; 178 in femur, 137 in tibia, 121 in fibula. Most had single foramen; femur (66%), tibia (96%) and fibula (94%). Number of foramina ranged from 0-3 in femur, 1-2 in tibia and 0-2 in fibula. Foramina were present mainly on the posterior surface of the bones [linea aspera in femur (96), below soleal line and lateral to the vertical line in tibia (90) and peroneal crest in fibula (74)]. The mean length, mean distance of nutrient foramen from the proximal end of the bones measured. Most foramina found on the middle third, with foraminal index ranging from 33% to 66%; though on tibia it's not a common finding. The 't' test value of foraminal index was significant for tibia. Mean foraminal index was measured for femur 42.28%, tibia 35.91%, fibula 41.54%.
Conclusion: The knowledge of anatomical variations of nutrient foramen is very important as preservation of vascularization of long bones is essential in fracture repair, tumor resection, bone grafting.

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1. Introduction

Nutrient foramina of long bones vary in number, size, position and location on the bones and in the direction towards which they point. Though many studies have been done on this topic in different parts of the world, there are bound to be differences in different countries as well as in different regions of the same country. Therefore, a comprehensive study was done on the variations in anatomy of nutrient foramina of lower limb long bones belonging to the eastern part of the country.

During growing years 80% of interosseous blood supply comes from the nutrient artery as stated by Trueta.[1] This artery pierces the cartilage or the mesenchyme from which the long bone develops. The point of entry is known as nutrient foramen. Generally there is a single artery which pierces the centre of the cartilage/ mesenchyme, the point from where the ossification of the long bone starts. A nutrient artery is a branch of one of the arteries present in the vicinity of the growing bone.[2–4]

Instances of multiple nutrient arteries supplying a bone have been mentioned in the literature ranging from two to nine in rare cases.[5] Sometimes the nutrient artery may be absent and then periosteal artery plays the role of dominant artery providing nutrition to the long bone.[2] This knowledge of vascularity of the long bones is important for a surgeon dealing with pathologies of these bones, in the fractures, resection of tumours, microvascular bone grafting etc.

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2. Materials and Methods

A total 393 adult bones, 138 femurs, 132 tibia and 123 fibulae of both sides were studied in the Department of Anatomy, Burdwan Medical College, Purba Bardhaman district, West Bengal. The bones were unidentified and were collected from the department used for teaching purpose and from the undergraduate and post-graduate students. The exact age and the sex of the bones was not determined. Broken and damaged bones were excluded from the study. Bones were studied for the number, position, length-wise location, size and the direction of the nutrient foramina. Total length (TL) of the bones taking the farthermost points as reference was measured using an Osteometric board (Figure 1). Distance of nutrient foramen (DNF) from the proximal end of the bone was noted. TL and DNF were used for detecting Foraminal Index (FI) using Hughe's formula.[6]

FI = (DNF/TL) x 100

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

TL = Total length of bone

All the findings were tabulated, studied in the light of already available data and inference was drawn.

3. Results

Out of 393 bones studied, 138 were femur, 132 tibia and 123 fibulae. Descriptive statistics is given in the Tables 1, 2 and 3.

Total number of NF found were 178 (68 right, 70 left) in femur, 137 (67 right, 65 left) in tibia, 121 (64 right, 59 left) in fibula.

Most bones had single foramen, femur (65.94%), tibia (96.21%) and fibula (93.50%). Number of foramina ranged from 0 to 3 in case of femur (Figure 2), 1or 2 in tibia (Figure 3) and 0 to 2 in fibula (Figure 4).

Foramina in all 3 types were mainly present on the posterior surface, femur (72.47%), tibia (100%) and fibula (100%). Commonest position in case of femur was linea aspera (53.93%), in tibia below soleal line and lateral to the vertical line (65.69%) and in fibula on peroneal crest (61.16%).

Mean TL and DNF of bones measured were 42.15cms and 17.82cms, 36.79cms and 13.21cms & 34.74cms and 14.43cms for femur, tibia & fibula respectively. Hence most of the NFs were present on the middle third of the bones. 79.78% femur, 86.13% tibia and 81.82% fibula had foraminal index ranging from 33% to 66%. Mean FI was 42.28%, 35.91%, 41.54% for femur, tibia and fibula respectively.

In femur all the foramina were directed towards the upper end except one. In tibia and fibula, foramina were directed towards the lower end except one in tibia and two in fibula, which were directed towards the upper end.

The range of foraminal index (FI%) of both sides in all the 3 types of bones were noted. Mean FI of two sides were compared. The 't' test value of FI was 0.03 for tibia. 'P' value < 0.05, thus the result was significant, that for the other two types of bones was not significant. (Table 4)

Fig. 1: Measurement of lengths of bones usingosteometric boards

Fig. 2: One right sided femur showing three nutrient foramina

4. Discussion

In case of any fracture, the knowledge of possible position and probable number of nutrient foramina is very important as the blood supply of any bone is of utmost importance in case of union of fracture or healing. In case of open reduction or internal/external fixation this knowledge

Table 1: Morphometric and topographic details of nutrient foramina of femur

Parameters	Right	Left	Total
Number of femur	68	70	138
Number of nutrient foramina	83	95	178
Mean TL (cm)	42.47	41.83	42.15
Mean DNF (cm)	17.63	17.99	17.82
Mean FI (%)	41.51	43	42.28
Number of nutrient foramina			
0	3	1	4 (2.9%)
1	48	43	91 (65.94%)
2	16	26	42 (30.43%)
3	1	0	1 (0.72%)
Position of nutrient foramina (on different surfaces)			
Spiral line	1	2	3 (1.69%)
Gluteal tuberosity	6	6	12 (6.74%)
Upper 1/3rd of posterior surface	6	9	15 (8.43%)
Linea aspera	60	36	96 (53.93%)
Medial surface	7	31	38 (21.35%)
Lateral surface	3	8	11 (6.18%)
Lower 1/3rd of posterior surface (popliteal surface)		2	2 (1.12%)
Lateral supracondylar line		1	1 (0.56%)
Length-wise location of the foramina			
Upper 1/3rd (FI < 33.33%)	13	17	30 (16.85%)
Middle 1/3rd (FI = 33.33% - 66.66%)	67	75	142 (79.78%)
Lower 1/3rd (FI > 66.66%)	3	3	6 (3.37%)
Direction of foramina	All towards upper end except one	All towards upper end	99.44%

Table 2: Morphometric and topographic details of nutrient foramina of Tibia

Parameters	Right	Left	Total
Number of Tibia	67	65	132
Number of nutrient foramina	69	68	137
Mean TL (cm)	36.93	36.65	36.79
Mean DNF (cm)	12.94	13.48	13.21
Mean FI (%)	35.04	36.75	35.91
Number of nutrient foramina			
0	0	0	0
1	65	62	127 (96.21%)
2	2	3	5 (3.79%)
3	0	0	0
Position of nutrient foramina (all on posterior surface)			
Above soleal line	8	10	18 (13.14%)
Medial to vertical line	17	12	29 (21.17%)
Lateral to vertical line	44	46	90 (65.69%)
Length-wise location of the foramina			
Upper 1/3rd (FI < 33.33%)	10	9	19 (13.87%)
Middle 1/3rd (FI = 33.33% - 66.66%)	59	59	118 (86.13%)
Lower 1/3rd (FI > 66.66%)	0	0	0
Direction of foramina	All towards lower end	All towards lower end except one	99.27%

Table 3: Morphometric and topographic details of nutrient foramina of Fibula

Parameters	Right	Left	Total
Number of fibula	64	59	123
Number of nutrient foramina	66	55	121
Mean TL (cm)	35.1	34.39	34.74
Mean DNF (cm)	14.85	13.95	14.43
Mean FI (%)	42.31	40.56	41.54
Number of nutrient foramina			
0	1	4	5 (4.06%)
1	60	55	115 (93.50%)
2	3	0	3 (2.44%)
3	0	0	0
Position of nutrient foramina (all on posterior surface)			
Above PC	8	6	14 (11.57%)
Interosseous border (IB)	4	6	10 (8.26%)
Peroneal crest (PC)	42	32	74 (61.16%)
Medial to PC	3	1	4 (3.31%)
Lateral to PC	5	7	12 (9.92%)
Below PC	4	3	7 (5.78%)
Length-wise location of the foramina			
Upper $1/3^{rd}$ (FI < 33.33%)	9	6	15 (12.40%)
Middle $1/3^{rd}$ (FI = 33.33% - 66.66%)	53	46	99 (81.82%)
Lower $1/3^{rd}$ (FI > 66.66%)	4	3	7 (5.78%)
Direction of foramina	All towards lower end except two	All towards lower end	98.35%

Table 4: Range, mean and p values of difference between 2 sides of lower limb long bones

	Range	Mean ± SD	p Value
Femur	26.86 - 69.48	42.75 ± 9.38	0.76
	28.01 – 69.63	43.19 ± 10.07	
Tibia	27.1 – 59.74	35.07 ± 3.74	0.03
	27.63 – 59.74	36.84 ± 5.71	
Fibula	26.4 – 71.12	42.63 ± 10.22	0.59
	29.91 – 81.92	43.66 ± 10.66	

Value < 0 05 is significant

becomes even more important so as to assess the location of implants and predict the prognosis.

In case of long bones of lower limbs, the location of nutrient foramina usually follows a definite arrangement, with some exceptions.

In the present study, more femora had single foramen (65.94%) followed by double nutrient foramina (30.43%), only a few had more than 2 or none. Mysorekar et al, in 1967 in Pune had found 45% femora with single and 50% with double foramina.[3] In their study, E Sendemir and A Cimen in the year 1991 observed in male excavated skeleton of byzantine era that only 26.6% femur had single and 46% had double foramina.[5] Pereira, G. A. M in 2011 observed that femur had 63.8% single & 34.9% double foramina in Brazilian population which was almost similar to the present study.[2] In their study Pedzisai Mazengenya and Mamorapelo D. Fasemore in 2015 observed that 63.8% & 34.9% of black South Africans had single and double foramina respectively whereas in case of white, it was 45% & 52.2%.[7] So the results of the present study were different from white South Africans. Joshi P in 2018 in Rajasthan[8] got similar results as ours (68% & 32%) whereas deviated results were obtained in studies done by BV Murlimanju in 2011 in Manglore (47.7% & 44.2%),[9] Mamta Sharma in 2015 (54% & 42%)[10] and Seema in 2015 (48.85% & 47.71)[11] in Punjab and Swapna A in 2016 in Maharashtra (46.2% & 19.2%).[12] Results of the study by Ranaweera L in 2020 on Shri Lankan population were also slightly different (58% & 36%).[13] Most of these studies suggest single foramen to be the commonest finding which is traversed by a single nutrient artery that should be preserved while operating on femur. A main nutrient artery is usually derived from the second perforating artery which is a branch of profunda femoris artery. As is evident two nutrient arteries supplying femur is also a common finding, they maybe branches from the first and third perforators.[4] More than

Fig. 3: One tibia showing two nutrient foramina

Fig. 4: One fibula showing two nutrient foramina

two arteries supplying femur maybe seen owing to its large size and can come from any of the perforators, medial circumflex, lateral circumflex or inferior gluteal arteries.

As for the position of the foramina in femur, this present study observed 53.93% foramina present on Linea aspera & 21.35% on the medial surface. Hence linea aspera was the commonest site as is also mentioned in Gray's anatomy.[4] Most of the other studies also showed higher percentage of foramina on the Linea aspera (E Sendemir 86.6%; Pereira, G. A. M et al 93.4%; Pedzisai Mazengenya et al Black 92.2% & white 85.3%; Ranaweera L et al 84%; Seema 76.50% and Joshi P 100%).[2,5,7,8,11,13] These differences in percentage will give better knowledge in case of east Indian population to understand the position of nutrient foramina.

The mean Foraminal Index of femur observed was 42.28% which is almost similar to that of Ranaweera L et al (43.52%); Pereira, G. A. M et al (43.7%) and Pedzisai Mazengenya et al (Black 41.87%).[2,7,13] But mean FI observed by BV Murlimanju et al (38.9%) was slightly lower,[9] that in other studies was slightly higher.[8,11,12] Femora of subjects outside India were in general longer than that of Indian subjects, slight variations in femora belonging to different parts of India was also observed. Even though the FI varies from country to country and also among different regions of the same country, they all found NF located on the middle third of the femur including the present study (79.78%). Hence we need to be more careful of preserving the blood supply in case of fracture or resection of tumors involving the middle third of femur.

NF were directed towards the upper end except the lower most foramen in the bone which had triple foramina (99.44%). (ref.pic) Lower end of femur is the growing end according to the 'growing end theory'.[14] Among other studies L. Ranaveera also found 98.67% NF to be directed towards the upper end.[13]

96.21% and 3.79% tibia in present study had single and double foramina which was close to the findings of Mamta Sharma (96% & 4%), Seema (95.05% & 4.95%) and Shambhu Prasad (95% & 5%).[10,11,15] In all these studies there were no tibia with no or more than 2 foramina. Results of studies by Collipal (94% & 6%) and Sendemir (94.8% & 5.2%) were also almost similar.[5,16] Findings of studies by Pereira, G. A. M (98.6% & 1.4%) and Pedzisai Mazengenya on white and black South African population (98.3% & 1.7% and 99.4% & 0.6%) differs from our study.[2,7] In their study BV Murlimanju and Puneet Joshi observed 1.4% and 6% tibia having no foramina which is different from the current study.[8,9] Swapna et al found 1.9% and 3.8% tibia with double and triple foramina which also differs from the present study.[12] Hence in all these studies most tibia had single NF whereas double, triple and no foramina is a rarity. Nutrient artery in tibia is generally branch of posterior tibial artery which needs to be preserved specially during external fixation of fractures. An extra artery can be a branch of anterior tibial artery before it leaves the posterior compartment or the popliteal artery at its bifurcation.[4]

In the present study, all the foramina in tibia were located on the posterior surface, mostly below the soleal line and lateral to the vertical line (65.69%) and some medial to the vertical line (21.17%) whereas according to Gray's anatomy nutrient artery to tibia usually lies near the soleal line.[4] Mysorekar and Mamta also suggested that the foramina were mostly present below soleal line and lateral to the vertical line (74%).[3,10] Others also mentioned the posterior surface as the major site for the foramina.[7,8,11,15]

There were variation in mean FI finding in most studies like that by Pereira, G. A. M et al (32.7%); Pedzisai Mazengenya et al (Black 31.66% & white 33.15%), Swapana (29%) and Shambhu Prasad (31.07%)[2,7,12,15] even though the mean length of tibia was almost same. The mean Foraminal Index of tibia was 35.91% in the current study i.e. most foramina were present on the middle third (86.13%), few on upper third (13.87%) and none in lower third of the bone. This finding differs from almost all studies done in the past where more number of foramina were found on upper-third of the bone. It has been noticed that almost half of the pins applied at the middle third of the tibia during external fixation for repair of tibia fractures cause injury to the sole nutrient artery of tibia. So wherever possible pin application should be avoided in the middle third of tibia.[17]

The direction of foramina was towards the lower end except in one tibia with double foramina (99.27%). Few other studies had also mentioned this [Shambhu Prasad (98.33%), P. Mazengenya (99.4% in black and 97.80% in whites)].[7,15] By the law of direction of nutrient foramina, the growing end of a bone is opposite to the end where the NF points. Hence the growing end of the tibia is its upper end. Most likely the bone where 2 foramina pointing in opposite direction are present, each end acts as a growing end alternately.[3]

Almost all the studies considered here mentioned that the maximum number of fibulae had single NF, only the percentage differs. Our finding of fibulae with single nutrient foramina (93.5%) is similar to that of Mysorekar (92.8%) and Mamta Sharma (92%).[3,10] Results of other studies vary from 63.5% (Swapna A) to even 100% (Forriol). E Sendemir et al (73.9%), Collipal (75%), P Mazengenya (white 86.1%, black 87.2%), Puneet Joshi (88%), BV Murlimanju et al (90.2%) and Periera (99.1%).[2,5,7–9,12,16,18] A single nutrient artery of fibula is a branch of fibular artery.[4] We also found few fibulae with no (4.06%) or double (2.44%) foramina but none with more than 2 foramina. BV Murlimanju[9] & Mamta[10] got 9.8% & 8% fibulae with no foramina but had not found double foramina. Here also our findings were close to Mysorekar[3] who found 3.9% and 3.3% bones with no and double foramina. It has been suggested that the bones which get no nutrient foramen must be supplied by periosteal arteries.[1] In case of double arteries, they are both branches of the fibular (peroneal) artery.[3]

In this study, all foramina (100%) were found to be present on posterior surface of fibula, mostly on the peroneal crest (58.73%) followed by posterior surface above the peroneal crest (11.11%). Gray's anatomy also mentions that NF is present a little proximal to the midpoint of the posterior surface.[4] In most of the other studies also [P Mazengenya [7]- South Africa (64.5% in blacks and 70.30% in whites), Collipal,[16] Chile (68%), Forriol[18] (67.50%)] foramina where mostly found on the posterior surface. Whereas Mysorekar et al[3] and Sendemir[5] found foramina on posterior surface only in 26% and 9.8% bones respectively.

The mean Foraminal Index of fibula was 41.54% in the current study; which is mostly lower than the studies done by Pereira, G. A. M et al[1] 46.1%; Pedzisai Mazengenya et al[7] Black 43.33% & white 46.86%, BV Murlimanju et al[9] 49.2% even though all the studies depict that the foramina were present on the middle third of the bones.

In most fibulae NF were directed towards the lower end except two (98.35%). Even though the 'periosteal slipping theory' by Humphry[19] states that the nutrient canal points away from the growing end, literature suggests few NF pointing towards the upper end of fibula.[7]

Fibula is the commonest bone used in vascularised bone grafting in any part of the body and gives excellent results. Hence the knowledge of variations in its morphological and morphometric parameters is essential.

5. Conclusions

Most of the of lower limb long bones that were studied had single foramen. Most of the foramina were present on the middle third of the posterior surface. NF mainly positioned on middle third of tibia was not found in most other studies. Linea aspera was the commonest position on femur, below soleal line and lateral to the vertical line in tibia and peroneal crest in fibula. All the foramina in femur were directed towards the upper end except one and towards the lower end in tibia and fibula except one in tibia and two in fibula. The 't' test value of FI was significant in tibia when compared on two sides, that for the femur and fibula was not significant.

These variations observed here can help the surgeons, radiologists and radiotherapists to more precisely localise the nutrient foramina in lower limb bones in the eastern Indian population which will help them to deal with the fractures and tumors more accurately. Results of the study are also relevant in medico-legal practice and anthropological surveys.

6. Source of Funding

None.

7. Conflict of Interest

None.

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