***Original communication***

# DIAPHYSEAL NUTRIENT FORAMINA OF ADULT HUMAN TIBIA - ITS POSITIONAL ANATOMY AND CLINICAL IMPLICATIONS

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## RESUMEN

El conocimiento del número y posición de los forámenes nutricios en los huesos largos es importante en los procedimientos ortopédicos, tales como la terapia de reemplazo de articulaciones, reparación de fracturas, injertos de hueso y micro-cirugía de hueso vascularizado. El presente estudio se llevó a cabo en el departamento de Anatomía, Colegio Médico Gubernamental de Amritsar. El estudio comprendió 100 tibias de humanos adultos obtenidas de 50 cadáveres masculinos y 50 femeninos. Todos los huesos del presente estudio presentaban el foramen nutricio situado en el tercio superior del eje y se dirigían hacia abajo. En la mayoría de los huesos, se encuentró lateral a la línea vertical en la superficie posterior de la diáfisis tibial. Las distancias medias de foramen nutricio de los extremos superior e inferior de la tibia eran mayores en los hombres en ambos lados. Además, estas mediciones mostraron valores más altos en los huesos de la mitad derecha. El conocimiento preciso de la ubicación de la forámenes nutricios en los huesos largos es útil en la prevención de las lesiones intra-operatorias en cirugía ortopédica, así como en cirugía plástica y reconstructiva y también es relevante en la práctica médico-legal.

***Palabras clave:*** *foramen nutricio; tibia; implicancias clínicas.*

## ABSTRACT

An understanding of the number and position of nutrient foramina in long bones is important in orthopedic procedures such as joint replacement therapy, fracture repair, bone grafts and vascularized bone microsurgery. The present study was conducted in the department of Anatomy, Govt. Medical College Amritsar. The study group comprised of 100 adult human tibiae obtained from 50 male and 50 female cadavers. All the bones of the present study depicted single nutrient foramen situated in the upper one third of the shaft and were directed downwards. In majority of the bones, it was located lateral to the vertical line on the posterior surface of tibial shaft. The mean distances of nutrient foramen from the upper and lower ends of tibia were found to be greater in males on both the sides. Also, these measurements showed higher values in the right sided bones. Precise knowledge of the location of the nutrient foramina in long bones is helpful in preventing intra-operative injuries in orthopedic as well as in plastic and reconstructive surgery and is also relevant in medicolegal practice.

***Keywords:*** *Nutrient foramen; Clinical implications; Tibia.*

## INTRODUCTION

The role of nutrient foramina in the nutrition and growth of the bones is evident from the term “nutrient” itself (Kate, 1971). The major blood supply to long bones is from the nutrient arteries, especially during the active growing period in the embryo and foetus, as well as during early phases of ossification (Lewis, 1956; Patake and Mysorekar, 1977; Forriol Campos et al, 1987).

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**Received**: 2 April, 2013. **Revised**: 7 May, 2013. **Accepted**: 28 July, 2013.

During childhood, the nutrient arteries provide 70-80% of the blood supply to long bones and when this supply is compromised, medullary bone ischemia occurs with less vascularization of the metaphysis and growth plate (Forriol Campos et al, 1987). Knowledge of the position of nutrient foramina is useful in both medicolegal practice and certain surgical procedures (Mysorekar, 1967). In medicolegal practice, it may be possible to estimate the total length of the bone, if one knows the ratio between the total length and the distance of nutrient foramen from both the ends. This is particularly important as sometimes incomplete bones broken at one end are sent for examination (Chhatrapati and Misra, 1967). The surgeon must acquire a detailed knowledge of the anatomy of the part on which he is to operate since the success of these operations depends to a large extent on a minimal interference with the blood supply of the bone (Laing PG, 1953). It is very important that the nutrient blood supply is preserved in free vascularized bone grafts so that the osteocytes and osteoblasts in the graft survive, and the healing of the graft to the recipient bone is facilitated with the usual replacement of the graft by creeping substitution (Gumusburun et al, 1994). In free vascular bone grafts a good supply is also necessary for preserving osteocytes in tumour resection and trauma, congenital pseudoarthrosis and cases of difficult nonunion of long bones for the successful development of a new vascular bed (Sendemir and Cimen, 1991).

| Sex/Side | Right Tibiae | Left Tibiae | Total |
|---|---|---|---|
| **Males** | 25 | 25 | 50 |
| **Females** | 25 | 25 | 50 |

**Table 1:** Table depicting the description of the study group (n=100)

Detailed data on the blood supply to the long bones and the association with the areas of bone supplied has continued to be a major factor in the development of new transplantation and resection techniques in orthopaedics (Kirschner, 1998; Kizilkanat, 2007).
A considerable interest in studying nutrient foramina resulted not only from morphological, but also from clinicopathological aspects. Some pathological bone conditions such as developmental abnormalities, fracture healing or acute haematogenic osteomyelities are closely related to the vascular system of the bone (Skawina and Wyczolkowski, 1987).
The rate of healing of a fracture is related to the vascular supply of the bone. The areas or regions with a good blood supply heal more rapidly than those with a poor blood supply. The tibia is a good example of such process. Because of the absence of nutrient foramina in the distal third of the tibia, fractures in that region tend to show delayed union or malunion (Trueta, 1974).

## MATERIALS AND METHODS

The material for the present study comprised of one hundred (100) adult human tibia bones of known sex and side, obtained from the department of anatomy, Govt. Medical College, Amritsar, Punjab, India. The study group comprised of 50 males and 50 females with equal number of right and left sided bones (see Table 1). The inter-condylar eminence and the tip of medial malleolus were used as bony landmarks to define the upper and lower ends of tibia respectively.
Following parameters were noted:
(1) Number of nutrient foramina on each tibia
(2) Situation of nutrient foramina in tibia (upper, middle or lower one third of the shaft)
(3) Direction of the nutrient foramina (upward/downward)
(4) Location of nutrient foramen in reference to the vertical line on posterior surface of tibial shaft. This vertical line normally divides the area below the soleal line into medial and lateral parts
(5) Distance of nutrient foramina from upper end of the bone
(6) Distance of nutrient foramina from lower end of the bone

The observations were meticulously recorded and tabulated. The morphometric values were subjected to statistical analysis using student's t-test. The findings were also discussed in the light of existing literature.

## RESULTS

This morphometric study conducted on adult human tibiae of north Indian population revealed the under-mentioned important observations. In all the hundred human tibiae, a single nutrient foramen was found in the upper one third of the posterior surface of tibial shaft and was directed

distally. Table 2 depicts the location of nutrient foramina in relation to the vertical line on posterior surface of the tibia. In most of the cases, it was situated lateral to the vertical line (89%) whereas only 11% of the tibiae showed presence of the nutrient foramen medial to the vertical line.
Table 3 shows the mean distance of nutrient foramina from upper and lower ends of the tibia on right and left sides in the two sexes. It is evident from the table that the distance of nutrient foramina from the upper end was more in males on both the sides but it was statistically significant only on the right side (p-value on right side 0.008 and on left side 0.196). Further, when compared between the two sides, this measurement was found to be greater on right side in both the sexes but the difference was statistically insignificant (p-value=0.111 in males and 0.735 in females).
The mean distance of nutrient foramina from the lower end of tibia was more in males on both the sides, the difference being statistically significant (p-value <0.001 on right side and 0.001 on left side). However, when compared between the two sides, the distance was more on right side in both the sexes but the difference was statistically insignificant (p-value=0.365 in males and 0.257 in females) (Table 3).

| Location of Nutrient Foramina | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lateral to vertical line | | | | On the vertical line | | | | Medial to vertical line | | | |
| Right (n) | | Left (n) | | Right (n) | | Left (n) | | Right (n) | | Left (n) | |
| M | F | M | F | M | F | M | F | M | F | M | F |
| 23 | 22 | 20 | 24 | - | | | | 02 | 03 | 05 | 01 |

**Table 2:** Table showing the location of nutrient foramina in relation to the vertical line on the posterior tibial shaft

| Reference Point | Distance (Mean + S.D (mm) x n) | | | |
|---|---|---|---|---|
| | Right (n) | | Left (n) | |
| | Male | Female | Male | Female |
| upper end | 118.76+8.89 (25) | 111.24+10.37 (25) | 114.40+10.10 (25) | 110.12+12.84 (25) |
| lower end | 259.44+16.58 (25) | 240.84+15.18 (25) | 254.60+20.66 (25) | 234.80+21.52 (25) |

**Table 3:** Table showing the distance of nutrient foramina with reference to upper and lower ends of tibia

## DISCUSSION

The diaphysis of the long bones is irrigated by one or more nutrient arteries that pierce through the compact bone and divide in the medullary cavity into ascending and descending branches (Collipal et al, 2007). The nutrient artery to a long bone may have various sources of origin, for example: in the tibia the origin can be directly from the popliteal or from the posterior tibial arteries. In the irrigation of long bones, the epyphisiary and metaphysiary nutrient arteries also participate, which are very important forming a series free of intrabone anastomosis (Collipal et al, 2007). Investigations on the vascular anatomy of the long bones are important to human because it is relevant to fracture treatment (Bridgeman and Brookes, 1996). The arrangement of the diaphyseal nutrient foramina in the long bones usually follows a definite pattern (Mysorekar, 1967).
The nutrient foramina have been studied for their position, exact site, number, direction of canal and distance from either end of the bone.
**1. Number of nutrient foramina**- Table 4 compares the number of nutrient foramina as

seen in the present study with the earlier ones. Toeing in line with majority of the earlier studies, only one nutrient foramen was seen in all the bones. However Kate (1971) found two foramina in majority of their bones.

*Clinical implications*: 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 (Kizilkanat et al, 2007). An absence of nutrient foramina in some bones has been observed, in which case the periosteal vessels become the sole source of the blood supply (Shulman, 1959).

| Authors (year) | Race | Number of bones with nutrient foramina | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | One | | | | Two | | | | Three | | | |
| | | Right (n) | | Left (n) | | Right (n) | | Left (n) | | Right (n) | | Left (n) | |
| | | M | F | M | F | M | F | M | F | M | F | M | F |
| Chattrapati(1967) | Indian (Gujarat) | 31 | | 38 | | - | | | | - | | | |
| Mysorekar (1967) | Indian (Poona) | 89 | | 89 | | 01 | | 01 | | - | | | |
| Kate (1971) | Indian (Nagpur) | 30 | | | | 160 | | | | 10 | | | |
| Longia (1980) | Indian (Jhansi) | 92 | | 98 | | 06 | | 04 | | - | | | |
| Collipal (2007) | Chile | 24 | | 23 | | 01 | | 02 | | - | | | |
| Kizilkanat (2007) | Turkish | 98 | | | | 02 | | | | - | | | |
| Present Study | North Indians | 25 | 25 | 25 | 25 | - | | | | - | | | |

**Table 4:** Table showing the number of nutrient foramina in tibial shaft by different authors with special reference to the present study

| Authors (year) | Race | Situation of Nutrient Foramen | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper one third | | | | Middle one third | | | | Junction of U/M* third | | | |
| | | Right (n) | | Left (n) | | Right (n) | | Left (n) | | Right (n) | | Left (n) | |
| | | M | F | M | F | M | F | M | F | M | F | M | F |
| Mysorekar(1967) | Indian (Poona) | 141 | | | | 39 | | | | 02 | | | |
| Kate (1971) | Indian (Nagpur) | - | | | | - | | | | 200 | | | |
| Longia (1980) | Indian (Jhansi) | 96 | | 97 | | 08 | | 09 | | - | | | |
| Collipal (2007) | Chile | 50 | | | | | | | | | | | |
| Present Study | North Indians | 25 | 25 | 25 | 25 | - | | | | - | | | |

**Table 5:** Table depicting the situation of nutrient foramina in relation to length of tibia in various studies with special reference to the present study. **U/M- Upper and Middle*

**2. Situation of nutrient foramen in relation to length of the bone-** Table 5 compares the situation of nutrient foramina in relation to length of bone as observed in present study with the previous studies. In most of the populations, it was present in the upper one third of the shaft except in Nagpur population where it was situated at the junction of upper and middle thirds of the shaft.

*Clinical implications*: Kizilkanat et al (2007) emphasized upon the importance of location of nutrient foramina in longitudinal stress fractures of tibia as these fractures can either initiate from the nutrient foramen or its superomedial aspect**.** They further related the delayed or nonunion in the middle or lower diaphysis following trauma to the absence of nutrient arteries entering the bones. Clinical fracture of a long bone is usually accompanied by rupture of the nutrient artery with variable disruption of the peripheral vessels associated with periosteal detachment. Following fracture the ruptured nutrient artery and periosteal vessels, together with those in the adjacent soft tissue, start local bleeding (Trueta, 1974). Longia et al (1980), Gumusburun et al (1994) land stress on the importance of preservation of nutrient blood supply in free vascular bone grafting to promote fracture repair as well as to facilitate graft healing in recipients.

**3. Direction of nutrient foramen-** It was found to be directed downwards in all cases of the present study as its relationship with the growing end of long bones has been enunciated in the Wolff's law that it seeks the elbow and flees the knee (Kate, 1971). The growing end is supposed to grow at least twice as fast as the other end (Longia et al, 1980). Only Longia et al (1980) encountered 3.5% of tibiae disobeying this law. According to Hughes (1952), there are variations in the direction of the nutrient foramina in many tetrapods and also some similarity in the nutrient foraminal pattern in mammals and birds.

| **Authors (year)** | **Race** | **Situation of Nutrient Foramina** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Lateral to vertical line** | | | | **On the vertical line** | | | | **Medial to vertical line** | | | |
| | | **Right (n)** | | **Left (n)** | | **Right (n)** | | **Left (n)** | | **Right (n)** | | **Left (n)** | |
| | | **M** | **F** | **M** | **F** | **M** | **F** | **M** | **F** | **M** | **F** | **M** | **F** |
| **Chattrapati (1967)** | **Indian (Gujarat)** | 38 | | | | 07 | | | | 12 | | | |
| **Mysorekar (1967)** | **Indian (Poona)** | 135 | | | | 20 | | | | - | | | |
| **Kate (1971)** | **Indian (Nagpur)** | 100 | | | | 20 | | | | - | | | |
| **Longia (1980)** | **Indian (Jhansi)** | 81 | | 88 | | 08 | | 05 | | 07 | | 05 | |
| **Present Study** | **North Indians** | 23 | 22 | 20 | 24 | - | | | | 02 | 03 | 05 | 01 |

**Table 6:** Table showing the situation of nutrient foramina in relation to vertical line on posterior surface of tibial shaft in previous studies with special reference to the present study.

| **Reference Point** | **Authors (year)** | **Race** | **Distance (Mean ± S.D (mm) n)** | | | |
|---|---|---|---|---|---|---|
| | | | **Right (n)** | | **Left (n)** | |
| | | | **Male** | **Female** | **Male** | **Female** |
| **upper end** | **Chattrapati (1967)** | **Indian (Gujarat)** | 113.80 (31) Range=82-136 | | 118.02 (38) Range=82-141 | |
| | **Present Study** | **North Indians** | 118.76±8.89 (25) | 111.24±10.37 (25) | 114.40±10.10 (25) | 110.12±12.84 (25) |
| **lower end** | **Chattrapati (1967)** | **Indian (Gujarat)** | 257.70 (31) Range=218-302 | | 203.54 (38) Range= 211-300 | |
| | **Present Study** | **North Indians** | 259.44±16.58 (25) | 240.84±15.18 (25) | 254.60±20.66 (25) | 234.80±21.52 (25) |

**Table 7:** Table showing the comparison of distance of nutrient foramina from the upper and lower ends of tibia with special reference to the present study

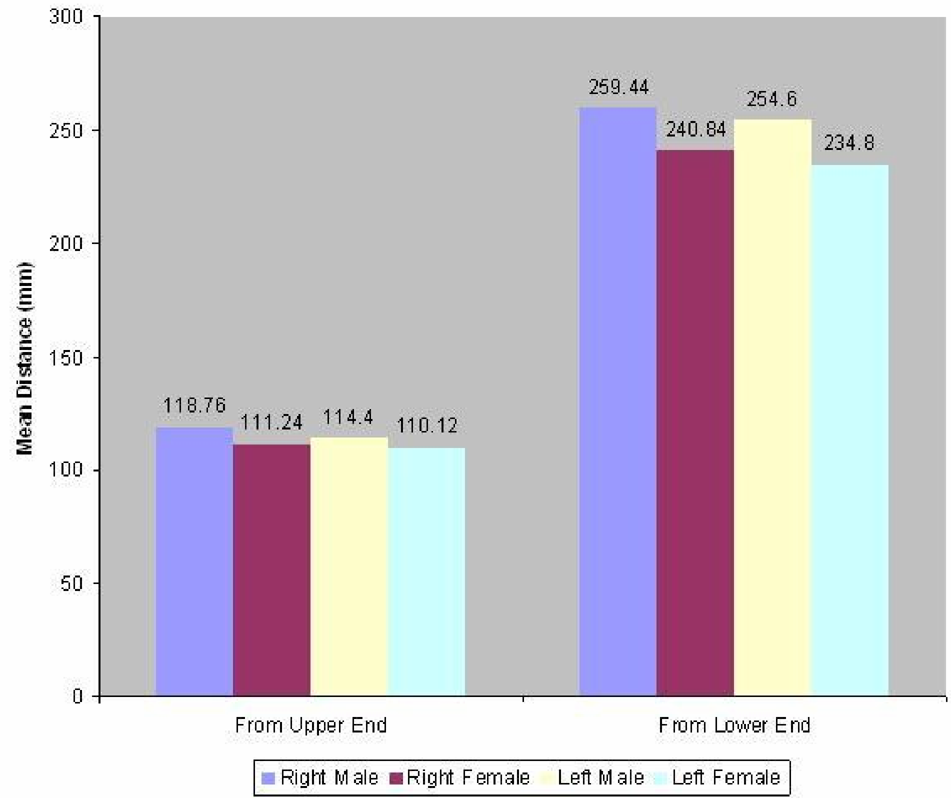
**4. Situation of nutrient foramen in relation to vertical line on posterior surface of tibia-** Table 6 depicts the situation of nutrient foramina in relation to vertical line on the posterior surface of tibial shaft in different populations. Hanging together with the earlier studies it was located lateral to the vertical line in majority of the bones of the present study.

*Clinical implications*: An accurate knowledge of the location of the nutrient foramina in long bones helps in preventing intraoperative injuries in orthopedic as well as in plastic and reconstructive surgery (Kizilkanat et al, 2007)**.** Preoperative planning of such procedures is vital for all such surgical interventions, together with an appropriate understanding of the extraosseous vascular supply for a successful outcome (Nagel, 1993)**.**

**5. Distance of nutrient foramen from the upper end of the tibia-** Table 7 compares the mean distance of nutrient foramina from the upper end of tibia as observed in the present study with the only study available in the literature.

The distance of nutrient foramina from the upper end of tibia was 118.76±8.89mm (Range=99-132mm) in males and 111.24±10.37mm (Range= 90-125mm) in females on right side. The corresponding values on left side were 114.40 ±10.10mm (Range=95-130mm) and 110.12-±12.84mm (Range=78-140mm) respectively.

When compared between the two sexes, on both the sides it was found greater in males, but the difference was statistically significant only on the right side (p-value on right side 0.008 and on left side 0.196). On the other hand, when compared between the two sides, it was greater on right side in both the sexes but the difference was statistically insignificant (p-value=0.111 in males and 0.735 in females). Earlier only one study had measured this distance in Gujarat population but irrespective of sex. They found it to be 113.80mm on right side and 118.02mm on left side (Chattrapati and Misra, 1967).




**Graphic 1:** Comparision of distance of nutrient foramina fom the upper and lower end of tibia

**6. Distance of nutrient foramen from the lower end of tibia-** Table 7 also compares the distance of nutrient foramen from the lower end of tibia as observed in the present study with the only earlier study by Chattrapati and Misra (1967). It was 259.44±16.58mm (Range=230-295mm) in males and 240.84±15.18mm (Range=210-270 mm) in females on right side. The corresponding values on left side were 254.60±20.66mm (Range=215-305mm) and 234.80±21.52mm (Range=187-270mm) in males and females respectively. When compared between the two sexes, it was greater in males on both the sides, the difference being statistically significant (p-value <0.001 on right side and 0.001 on left side). However, when compared between the two sides, the distance was greater on right side in both the sexes but the difference was statistically insignificant (p-value=0.365 in males and 0.257 in females). Earlier only one study had measured distance of nutrient foramina from the lower end of tibia in Gujarat population and found it to be 257.70mm on right side and 203.54mm on left side irrespective of sex (Chattrapati and Misra, 1967).

It also became evident from the present investigation that distance of nutrient foramina from the lower end of tibia is greater than its distance from the upper end of tibia (table 7) (Graphic 1).

The current study revealed presence of a single distally directed nutrient foramen in the upper one-third of posterior surface of all the tibiae. In 89% cases, it was located lateral to the vertical line on the posterior surface of tibial shaft. The distances of nutrient foramen from upper and lower ends of tibia were greater in males as compared to females. Further, these values were greater on the right sided bones in both sexes. The differences between the two sexes were statistically significant but those between two sides were statistically insignificant.

We aimed to investigate the precise topography of nutrient foramina in adult human tibiae of Indian subjects. This knowledge is of tremendous significance to Orthopaedic surgeons performing procedures involving bone grafts, fracture repair, joint replacement and vascularized bone microsurgery. Undoubtedly, the study is also relevant for medicolegal experts in establishing the identity of an individual.

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