Original Article

Morphological variations of nutrient foramina in lower limb long bones

Sharma M[1], Prashar R[2], Sharma T[3] Wadhwa A[4], Kaur J[5]

[1]Dr Mamta Sharma
MS, Associate Professor
[2]Dr Rajeev Prashar
MS, PCMS, Dep. of Surgery
Civil Hospital Kapurthala, Punjab, India
rprashardr1195@rediffmail.com
[3]Dr Tripta Sharma
MS, Professor
triptasharma140851@gmail.com
[4]Dr Ambica Wadhwa
MS, Professor
ambicasoni02@yahoo.com
[5]Dr Jasveen Kaur
MS, Assistant Professor
jsvn.kr@gmail.com
[1,3,4,5]Department of Anatomy
Punjab Institute of Medical Sciences
Jalandhar, Punjab, India

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Correspondence to:
Dr Mamta Sharma
rprashardr1195@rediffmail.com
9463369191

ABSTRACT

Background: *The major blood supply to long bone is from the nutrient arteries, which enter through nutrient foramina. Nutrient foramen is an opening into the bone shaft which give passage to the blood vessels of the medullary cavity of a bone The direction of the nutrient foramen of all bones is away from growing end and has a particular position for each bone.*

Objective: *The aim of the present study was to study the topographic anatomy and morphology of the nutrient foramina in human adult lower limb long bones.*

Material and Method: *The study was performed on 150 lower limb long bones which included 50 femora, 50 tibiae and 50 fibulae. The bones were obtained from department of anatomy, Punjab Institute of Medical Sciences, Jalandhar.*

Results: *The variations were found in number and location of nutrient foramen in different lower limb long bones. In femur double and triple foramina were observed. Absence of nutrient foramen was observed in femur and fibula.*

Conclusion: *The topographical knowledge of these foramina is useful in certain operative procedures, in orthopedics as well as in plastic and reconstructive surgery, to avoid damage to the nutrient vessels.*

Key Words*: Nutrient foramen, nutrient artery, femur, tibia, fibula, Linea aspera, diaphysis*

Introduction

The role of nutrient foramina in the nutrition and growth of the bones is evident from the term 'Nutrient' itself. [1] Nutrient foramen is an opening into the bone shaft which give passage to the blood vessels of the medullary cavity of a bone. The major blood supply to long bone is from the nutrient arteries, which enter through nutrient foramina especially during the active growing period in the embryo and foetus, as well as during phases of ossification. [2-4] During childhood, long bones receive about 80% of the interosseous blood supply from the nutrient arteries, and in the case of their absence, the vascularization occur through the periosteal vessels. [5] There are considerable intracortical anastomoses between the inner medullary and outer periosteal vessels. [6] The vascularization of the long bones generally is given by one or two diaphyseal nutrient arteries and numerous metaphysiary and epiphysiary arteries. The diaphyseal nutrient arteries obliquely penetrate in the diaphysis of the long bones, there entrance point and angulation being relatively constant dividing into ascending and descending branches. [7] The nutrient canal (through which nutrient artery enters the shaft) typically become slanted during growth, the direction of slant from surface to marrow cavity points towards the end that has grown least rapidly. This is due to greater longitudinal growth at the faster growing end. The direction of the nutrient foramen of all bones is away from growing end. [8] Most of the nutrient arteries follow the rule, ' to the elbow I go, from the knee I flee' but they are variable in position. This is because one end of the limb bone grows faster than the other do. [9] So, the direction of nutrient canal is important to denote the growing end of a bone. The nutrient foramen is distinguished from any other foramen by the presence of distinct vascular groove outside the nutrient foramen. [1, 10]

The nutrient foramen has a particular position for each bone. [11] In femur nutrient foramina, directed proximally, appear in the linea aspera varying in number and size, one usually near its proximal end second usually at its distal end. The main nutrient artery is usually derived from 2nd perforating artery. If two nutrient arteries occur, they may branch from 1st and 3rd perforators. The distal metaphysis has many vascular foramina. Arterial supply here is from genicular anastomosis. The periosteal vessels arise from the perforators and from the profunda femoris, and run circumferentially rather than longitudinally. [12]

In tibia, a faint vertical line descends from the centre of the soleal line for a short distance before becoming indistinct. A large vascular groove adjoins the end of the line and descends distally into a nutrient foramen. The proximal end of the tibia is supplied by metaphyseal vessels from the genicular arterial anastomosis. The nutrient foramen usually lies near the soleal line and transmits a branch of the posterior tibial artery: the nutrient vessel may also arise at the popliteal bifurcation or as a branch from the anterior tibial artery. On entering the bone the nutrient artery divides into ascending and descending branches. The periosteal supply to the shaft arise from the anterior tibial artery and from muscular branches. The distal metaphysis is supplied by branches from the anastomosis around the ankle. [12]

In fibula nutrient foramen is present a little proximal to the midpoint of the posterior surface and is directed distally. It receive a branch of the fibular artery. An appreciation of the detailed anatomy of the fibular artery in relation to the fibula is fundamental to the raising of osteofasciocutaneous free flaps incorporating segments of the bone. Free vascularized diaphysis grafts may also be taken on a fibular arterial pedicle. The proximal and distal ends receive metaphyseal vessels from the arterial anastomosis at the knee and ankles respectively. [12]

Knowledge about location of these foramina is useful in certain operative procedures to preserve the circulation. [13-15] The fibulae are used as vascularized graft for conditions such as stabilization of lost mandible, spine and even in tibia. Free vascularized fibular graft offers a reliable method of construction after excision of bone tumour and other bony defects. [16]

A considerable interest in studying nutrient foramina resulted not only from morphological but also from clinical aspects. Nutrient foramina reflect to a certain degree the bone vascularization. Some pathological bone conditions such as developmental abnormalities,fracture healing or acute hematogenic osteomyelitis are closely related to the vascular system of bone. [17] Longia GS etal observed that the position of nutrient foramina was on the flexor aspect in their human long bone specimen. [18]

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. [11, 18]

Humphrey who worked on the direction and obliquity of nutrient canals postulated periosteal slipping theory, the canal finally directed away from the growing end. [19] Harris has stated that the position of nutrient foramina is constant during the growth of long bones. [20] Lutken has stated that position of nutrient foramina is variable and typical position of nutrient foramina can be determined after a study on human bones. [10]

Henderson reported that their position in mammalian bones are variable and alter during growth. Though the foramina are directed away from the growing end, their topography might vary at the non growing end. So the topographical anatomy of the nutrient foramina may be worth. [21] The topographical knowledge of these foramina is useful in certain procedures to preserve the circulation. Therefore it is important that the arterial supply is preserved in free vascularized bone grafts so that osteocytes and osteoblasts survive. [22]

Also the study of relative relationship between the length of bone and distance of nutrient foramen from either end is useful in calculating the length of long bone from a given fragment which is important in medicolegal and anthropological work. From the length of the long bones height of an individual can be reconstructed. [18] An understanding of the location and 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 medicolegal cases. [23]

The aim of the present study was to study the topographic anatomy and morphology of the nutrient foramina in human adult lower limb long bones.

Material and methods

The study included 150 lower limb cadaveric long bones which included 50 femora 25 right, 25 left), 50 tibiae (25 right, 25 left), 50 fibulae (25 right, 25 left). The bones were obtained from osteology section of department of anatomy, Punjab Institute of Medical Sciences, Jalandhar. All the bones were macroscopically observed for number, location and direction of nutrient foramina. A magnifying lens was used to observe the foramina. The nutrient foramina were identified by the presence of a well marked groove leading to them and by a well marked, often slightly raised, edge at the commencement of the canal. Only diaphyseal nutrient foramina were observed in all the bones. Foramina at the ends of the bones were ignored. For determining the topographical distribution of nutrient foramen along the length of the bones, each bone was divided into 3 parts (upper, middle, lower1/3rd) after measuring the length of bone. Each part was noticed for the presence of nutrient foramen.

Results

In case of femora, 54% (27 out of 50) had single nutrient foramen, 42% (21 out of 50) had double foramina , 2% (1 out of 50) had triple foramina and it was absent in 2% (1 out of 50) cases.

In 54% femora (27 out of 50) showing single foramen, it was located on the proximal part of linea aspera in 44.4% (12 out of 27). In 41% (11 out of 27) it was found medial to medial lip of linea aspera in its distal part. But in15% (4 out of 27) it was observed on the distal part of linea aspera.

In 42% femora (21 out of 50) showing double foramina (Fig. 1) the location of nutrient foramina was quite different. In 71% (15 out of 21), one nutrient foramen was located on the proximal part of linea aspera and another was located on the distal part of linea aspera. In 9.5% femora (2 out of 21) one nutrient foramen was located just below the spiral line and another was medial to medial lip in distal part.

Fig. 1 Femora showing double nutrient foramina at different locations

In another 9.5% (2 out of 21) nutrient foramina were found on linea aspera, one on upper and another on middle part, about 2 cm apart. In 4.7% (1 out of 21), one nutrient foramen was located between spiral line and gluteal tuberosity and another one was on the medial lip of linea aspera in distal part. In another 4.7% (1 out of 21) , upper nutrient foramen was located on lateral lip of middle part of linea aspera and another one located just 1 cm below the previous one but it was medial to medial lip of linea aspera. In single femur 2% (1 out of 50) (Fig 2) showing triple foramina, upper nutrient foramen was located on gluteal tuberosity, middle one was on proximal part of linea aspera and lower one on the medial lip of linea aspera in distal part of it.

Fig. 2 Femur showing triple foramina

In case of tibiae, 96% tibiae (48 out of 50) had single nutrient foramen seen in relation to vertical line on the posterior surface of tibia. Out of this in 75% (36 out of 48) (Fig. 3) it was found lateral to vertical line, in 23% (11 out of 48) (Fig 4) it was found on the vertical line and in 2% (1 out of 48) tibia it was observed medial to vertical line. The double nutrient foramina was found in remaining 4% tibiae (2 out of 50) (Fig 5). One foramen was lying lateral to vertical line and another was located on the interosseous border in the middle of shaft.

With respect to fibulae, we observed that 92% fibulae (46 out of 50) (Fig 6) had single nutrient foramen. In the remaining 8% (4 out of 50) of the cases, nutrient foramen was absent. In the present study none of the fibulae showed the multiple foramina.

Discussion

Many studies reported that majority of femora studied had a single foramen in most specimen. [10,24-25] Some authors observed that the majority of femora had double nutrient foramina[7,13] According to other authors, the double nutrient foramen of femur was observed in 60% ,[2] 42.8%,[26]46%[27] and 55.6% cases.[28]Some researchers found three nutrient foramina in small number of femora.[7,26] Some researchers have observed nutrient foramen upto 6 to 9 [27] while some studies found the absence of nutrient foramina too. [13, 25]

Fig. 3 Nutrient foramen lying lateral to vertical line

Fig. 4 Tibia showing single nutrient foramen on the vertical line

Fig. 5 Tibia showing double nutrient foramina

In the previous studies have reported single nutrient foramen in 90 % of the tibiae, they have reported the presence of double nutrient foramina in some of the tibiae. [13, 18, 26]

In case of fibulae, single nutrient foramen was reported in 86.4%, [15] 94%, [29] 94.9% [30] and 100%. [2] The absence of nutrient foramina in long bones is well known. [26, 31] It was reported that in instances where the nutrient foramen is absent, the bone is likely to be supplied by periosteal arteries. [4] In previous studies double nutrient foramen was observed in 11.7% cases [26] and triple foramina were observed in one fibula. [15]

In 43.5% fibulae (20 out of 46) showing single nutrient foramen, it was located on medial crest (Fig 6). In 26.1% (12 out of 46) it was found between medial crest and interosseous border. In 17.4% (8 out of 46) it was observed between medial crest and posterior border and in 13% (6 out of 46) it was located on interosseous border.

Fig 6-Fibula showing single nutrient foramen on medial crest

So knowledge of nutrient foramen is important for orthopaedic surgeons preoperatively to preserve the circulation in open reduction of fractures, joint replacement therapies and in bone graft surgeries.

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