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Variations in Diaphyseal Nutrient Foramina in Human Lower Limb Long Bones

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Original scientific paper

Abstract
The aim of the present study was to study the diaphyseal nutrient foramina in human lower limb long bones. The material of the this study consisted of 90 adult human long bones of the lower limbs (30 femora, 30 tibiae, 30 fibulae). For each bone, the number and position of their nutrient foramina were studied. With the exception of femur, the majority of nutrient foramina in all bones studied were single in number and were secondary in size. Most of the nutrient foramina were concentrated in the middle third of the bone with the exception of tibia in which nutrient foramina were predominantly observed in its proximal third. Nutrient foramina were mostly located on the posterior surface of the shaft of bones of lower limb. The direction of nutrient foramina followed the growing end theory, with variations in the direction observed in some fibulae. The results of the present study confirmed previous findings regarding the number and position of nutrient foramina in the long bones of the lower limbs and provided clinical information concerning the nutrient foramina which could be useful as reference for surgical procedures.

Key words: **Nutrient foramina; Long bones; Lower limb; Vascularization.**

Introduction

The nutrient foramina are cavities that conduct the nutrient arteries and the peripheral nerves. The major blood supply for long bones originates from the nutrient arteries, mainly during the growing period and during the early phases of ossification. 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 occurs through the periosteal vessel. Bones are structures that adapt to their mechanical environment, and from a fetal age adapt to the presence of naturally occuring holes. These holes or nutrient foramina, allow blood vessels to pass through the bone cortex (1). The nutrient artery is the principal source of blood supply to a long bone and is particularly important during its active growth period in the embryo and fetus, as well as during the early phase of ossification (2). When this supply is compromised, medullary bone ischemia occurs with less vascularization of the metaphysis and growth plate (3). The diaphyseal nutrient arteries obliquely penetrate in the diaphysis of the long bones, their entrance point and angulations being relatively constant, dividing in ascending and descending branches, once they reach the medullary cavity. It has been suggested that the direction of the nutrient foramina is determined by the growing end of the bone. 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 osteomyelities are closely related to the vascular system of the bone (4). Detailed data on the blood supply to the long bones and the association with the areas of bone supplied has been continued to be a major factor in the development of new transplantation and resection techniques in orthopaedics (5).

Material and Methods

We analyzed 90 long bones of lower limbs from the from the osteology collection held in the Department of Anatomy, Faculty of Medicine, University of Sarajevo. They were divided into three groups 30 bones of each (30 femora, 30 tibia and 30 fibula). The laterality of the bones was the only known data, and right side and left side bones were identified; data about their age and gender were not available. The localization and number of nutrient foramina were analyzed in each bone. The nutrient foramina were observed in all bones with the help of a hand-lens. They were identified by their elevated margins and by the presence of a distinct groove proximal to them. Only well-defined foramina on the diaphysis were accepted.

The following data were studied on the diaphyseal nutrient foramina of each bone: **Number:** Bones were examined for the number of nutrient foramina. **Position:** The position of the foramina was divided as follow: the foramen was in the proximal third of the bone, foramen was in the middle third of the bone, and the foramen was in the distal third of the bone. The results were analyzed and tabulated using the Statistical Package of Social Sciences (SPSS) 8.0 windows.

Results

Femur

Number: In the whole series of 30 femora examined, 10(33.3%) had a single foramen and 16(48%) had double foramina. **Position:** Of the total 42 foramina, 6(14.3%) were in the proximal third and 36(85.7%) in the middle third. There were no foramina in the distal third. Of all femoral foramina, 10(23.8%) were on the medial lip of the linea aspera, 7(16.7%) on the lateral lip of linea aspera, 7(16.7%) on the posteromedial surface, 8(19%) between the two lips of linea aspera, 5(11.9%) on the gluteal tuberosity, 3(7.1%) medial to spiral line and 2(4.8%) on the posterolateral surface.

Tibia

Number: The whole series of 30 tibiae examined had a single nutrient foramen. **Position:** Of the total 30 foramina, 25(83.3%) were in the proximal third and 5(16.66%) were in the middle third. There were no foramina in the distal third. All foramina were located on the posterior surface of the tibiae, 17(56.66%) were closer to the interosseous border, 8(26.66%) were midway between interosseous border and soleal line and 5(16.66%) were on the posterior surface closer to the soleal line

Fibula

Number: Out of 30 fibulae examined, 23(76.66%) showed a single foramen while 7(23.33%) had double foramina. **Position:** The nutrient foramina of fibulae were situated in the middle third of the bone. Of the total 37 foramina, 33(89.2%) existed in the middle third and 4(10.8%) were in the distal third. There were no foramina in the proximal third. Of the whole fibular foramina, 23(62.2%) were on the medial crest of the posterior surface, 11(29.7%) on the posterior surface between medial crest and interosseous border and 3(8.1%) on lateral surface.

Discussion

In the previous literatures, a discrepancy was noticed regarding the number of nutrient foramina in the femora. Many authors stated that the majority of femora studied had double nutrient foramina (3,6,7), while others reported the presence of a single foramen in most specimens (8,9). Three nutrient foramina were observed in a small number of femora (2.19%- 10.7%) by many authors (3,6,7,8). It was interesting to find studies reporting a number of nutrient foramina as high as six (9) and up to nine (10), while others confirmed the absence of nutrient foramina in some femora (9,11). In this study, the whole series of tibiae examined had a single nutrient foramen. Previous studies reported the presence of a single nutrient foramen in at least 90% of the tibiae. But, in contradiction with the present results, they also reported the presence of double nutrient foramina in some of the tibiae (3,6,7,9,10). In the fibulae studied, 76.66% of the bones presented a single nutrient foramen, while 23.33% of the bones possessed double nutrient foramina. Similar data had been reported by Forriol Campos et al (3) and Sendemir and Cimen (10), while Mckee et al. (12) reported fibulae with three nutrient foramina. On the other hand, Mckee et al. (12), Gumusburun et al. (9) and Kizilkanat et al. (13) reported fibulae with no nutrient foramina. In the present study, most of the nutrient foramina (85.7%) were located along the middle third of the femur; the rest were in the proximal third, with no foramina detected in the distal third of the femur. These results were in accordance with those of Laing (8), Mysorekar, Forriol Campos et al. (3), Sendemir and Cimen (10), Gumusburun et al. (9) and Kizilkanat et al. (7). Laing (8) attributed the lack of the nutrient foramina in the lower third of the femur to the absence of vessels entering this part of bone. In our study, 83.33% of the nutrient foramina in the tibiae were in the proximal third and 16.66% in the proximal third. There were no foramina in the distal third. Similarly, many authors reported the presence of the majority of nutrient foramina in the proximal third of the tibia (6,7). On the other hand, Kizilkanat et al. (13) stated that most of nutrient foramina were located in the middle third. In the present series, all nutrient foramina studied were located on the posterior surface of the tibiae. Similar results were reported by Forriol et al. (3), Sendemir and Cimen (10), Nagel (6), Gumusburun et al. (9) and Collipal et al. (7). 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 are more rapidly healed 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 (14). In the present series, most of the nutrient foramina of the fibula were situated in the middle third of the bone (89.2%). The rest of the nutrient foramina (10.8%) were located in the distal third of the bone. These results were in agreement with most of the previous studies (3,9,10,12). On other hand, Guo (15) reported that the majority of foramina were located in the proximal third of the fibula. In this study, 62.2% of the fibular foramina were located on the medial crest and 29.7% on the posterior surface. However, some authors observed more nutrient foramina on the posterior surface compared to those on the medial crest (3,9,12). Others, (10) reported that the majority of foramina were on the medial surface of the fibula. Knowing the variations in the distribution of the nutrient foramina is important preoperatively, especially regarding the fibula used in bone grafting. In the majority of the specimens, the nutrient foramina were located in the middle third of the fibula which is the segment that must be used for the transplant, if one desires that the implant include endosteal vascularization and peripheral vascularization (7,12). 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 (9). The present study proved that most of the nutrient foramina were observed to lie on the flexor surface of the bones. Thus, on the humerus, radius and ulna they were mostly on the anterior surface while on the femur, tibia and fibula, they were located on the posterior surface. Kizilkanat et al. (13) stated that the position of the nutrient foramina was directly related to the requirements of a continuous blood supply to specific aspects of each bone, for example where there were major muscle attachments. It might be that, being more bulky, stronger and more active, flexors need more blood supply compared to extensors of limbs.

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 (13). Longitudinal stress fractures are more commonly associated with the tibia, but occasionally occur in the femur and fibula. Knowing the position of nutrient foramina is important in longitudinal stress fractures, as they can either initiate from the nutrient foramen or its superomedial aspect. The foramen may be a potential area of weakness in some patients and, when under stress because of increased physical activity or decreased quality of the bone, the foramen may allow development of a fracture. Position of the fracture relative to the nutrient foramen of the long bone and the patterns of edema are the secondary signs in the key of the diagnosis of this type of fracture (16). Investigations on the vascular anatomy of long bones are important to human because it is relevant to fracture treatment (11,17). There may be instances in which the vascular integrity of a long bone is vital, and knowledge of the nutrient anatomy may be of value to the orthopaedic surgeon. The surgical exposure and periosteal stripping in open reduction internal fixation procedures of diaphyseal fractures present further vascular insult to existing osseous injury. Depending upon the desired effect of internal fixation, its devices often require different bony surface exposures. Some of these extensiles exposure may involve dissection in regions of the nutrient artery. It must be borne in mind that any injury to the nutrient arteries of the bones must be avoided. This will entail careful consideration as to their origin from the main trunks and situation where they enter the bones. The healing of fractures, as of all wounds, is dependent upon blood supply, Injury to the nutrient artery at the time of fracture, or at subsequent manipulation, may be a significant factor predisposing to faulty union.

Conclusion

The study confirmed previous reports regarding the number and position of the nutrient foramina in the long bones of the lower limbs. It also provided important information to the clinical significance of the nutrient foramina. Exact position and distribution of the nutrient foramina in bone diaphysis is important to avoid damage to the nutrient vessels during surgical procedures. This study recorded data related to the population of Bosnia and Herzegovina, providing ethnic data to be used for comparison and that may help in surgical procedures and in the interpretation of radiological images.

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