

Number and position of nutrient foramina in humerus, radius and ulna of human dry bones of Indian origin with clinical correlation

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Abstract

Introduction

The aim of the study was to evaluate the number and position of the nutrient foramina in the humerus, radius and ulna of dry bones of Indian origin and correlate the findings clinically.

Materials and Methods

Among 260 bones studied, 100 (56 right and 44 left) were humeri and 80 (40 left and 40 right) radii and 80 ulnae (40 left and 40 right). Location and number of nutrient foramina were analysed, and length of bone, distance of nutrient foramina from proximal end of bone, anteroposterior and transverse diameters at the level of nutrient foramina were measured. Statistical analysis was performed for central tendency. Student's *t*-test was used to assess statistically significant correlation between number of nutrient foramina and size of bone. Foraminal index was calculated using Hughes formula.

Results

All bones had nutrient foramina directed towards the elbow. Mean distances of nutrient foramina from proximal ends were 17.70 ± 2.12 , 8.39 ± 2.33 and 9.00 ± 1.55 cm for humerus, radius and ulna, respectively. Nutrient foramen was absent in 4% humeri, 5% radii and 3.75% ulnae, and double in 4% humeri and 2.5% radii. No correlation was found between number of nutrient foramina and size of bones, i.e. length or diameter. Majority (76.92%) of bones

had nutrient foramina in the middle third of the shaft; whereas the distal third was a rare position. Nutrient foramina were most commonly present in the anteromedial surface for the humerus (67%) and anterior surface for both radius (66.25%) and ulna (76.62%).

Conclusion

The study provides important information about morphology and topography of nutrient foramina in upper limb long bones and knowledge of which is useful in planning orthopaedic procedures.

Introduction

The nutrient artery is a principal source of blood supply to long bones and is particularly important during their active growth period in the embryo and foetus, as well as during the early phase of ossification¹. Nutrient foramen (NF), through which the nutrient artery enters the bone, is directed obliquely, and edges of the oblique part are elevated for entrance of the nutrient artery^{2,3}. NF is always directed away from the growing end, commonly explained by the phrase 'seek the elbow and flee from the knee', and this can be explained on the basis of a simple fact that the artery has to slant towards that end of the bone which grows slower.

Knowledge about precise location and direction of the nutrient artery of long bones with its common variations is of supreme importance during any surgical or orthopaedic procedures of limbs, such as bone grafts and microsurgical vascular bone transplantations⁴. Although few reports are available on morphological

and topographical analysis of NF in upper limb long bones³⁻⁵, studies on variations in the incidence, direction and position of NF in long bones of the upper limb are scarce, particularly in Indian population. The present study was thus conducted to provide information on morphology and topography of NF in human upper limb long bones of Maharashtrian population from India and discuss their clinical significance.

Materials and Methods

The protocol of this study has been approved by the relevant ethical committee related to our institution in which it was performed.

The study sample comprised 285 fully ossified adult upper limb long bones, not necessarily paired, of unknown sex, obtained from the department of anatomy, Armed Forces Medical College, Pune, India. After excluding fragmented bones, bones with incomplete ossification, with any signs of gross pathology or distortion, a total 260 bones were included in the study. Out of 100 humeri, 56 were right and 44 left, 80 radii (40 left and 40 right) and 80 ulnae (40 right and 40 left).

The NF was identified by the groove leading to NF. Similarly slightly raised margins at edges of the NF also helped in its identification. A 26-gauge needle was passed through the foramen to confirm its direction (see Figure 1). In case of presence of multiple foramina, the largest NF was considered to be principal NF.

Location, direction and number of NF as well as its topography in relation to borders and surfaces of

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Figure 1: A 24-gauge surgical needle used to confirm the depth and slope of nutrient foramen.



Figure 2: Double nutrient foramina in the shaft of humerus indicated by arrows.

diaphysis were observed. NF within 1 mm from any border was taken to be lying on that border. Following objective parameters were measured using either the osteometre (accuracy of 0.1 cm) or digital vernier callipers (accuracy of 0.01 mm):

1. total length (L) of the bone;
2. distance (D) of centre of NF from proximal end of bone;
3. anteroposterior diameter (APD) of bone at the level of NF;
4. transverse diameter (TD) of bone at the level of NF and

5. foraminal index (FI) was calculated using Hughes formula⁶:

$$FI = (D/L) \times 100.$$

Based on FI of bones studied, they were classified into one of the three types. Foraminal index below 33.33 indicates that NF is in the proximal third of the bone and the bone is classified as type I; FI between 33.34 and 66.66 indicates NF is in middle third, which is type II and FI more than 66.67 indicates that NF is in the distal third of the bone, which is type III.

All observations and measurements were done by the first author to avoid observer bias; three measurements were made and mean was taken. Data were analysed for central tendency and descriptive statistics were performed. Paired *t*-test was used to study the statistically significant difference between number of NF and size of bone, i.e. length and diameters at the level of NF. *P*-value <0.05 was considered to be significant. These results were compared with findings of similar studies conducted nationally and internationally, and an attempt was made to know any clinical correlation.

Results

All NF in upper limb long bones under the study were directed towards the elbow; towards the distal end in the humerus; and towards the proximal end in the radius and ulna, with no exceptions. Mean distances of NF from proximal ends were 17.70 ± 2.12 , 8.39 ± 2.33 and 9.00 ± 1.55 cm for the humerus, radius and ulna, respectively. Total L of the bones, APD and TD at the level of NF are shown in Table 1. Numbers of NF are shown in Table 2, location of NF in Table 3 and classification into three types based on FI is shown in Table 4. Out of the 260 bones, 11 did not have NF and 6 had double NF (see figure 2). No correlation was found between length and diameter of bone with absence or duplication of NF (*P*-value < 0.05).

Discussion

Intact arterial supply is very important for healing of a fractured bone⁷. NF is the external opening of the nutrient canal. The vessel that initially invaginates ossifying cartilage at the centre of ossification acts as a nutrient artery and lies in the nutrient canal within NF⁸. The fibula showed anomalously directed NF due to its peculiar ossification pattern stated by Mysorekar. He also found no relation between length and number of foramina of bones⁹. It was suggested

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Table 1 Mean length and anteroposterior and transverse diameters at the level of NF

| Bone | Length \pm SD (cm) | | | AP diameter \pm SD (mm) | | | Transverse diameter \pm SD (mm) | | |
|---------|----------------------|------------------|------------------|---------------------------|------------------|------------------|-----------------------------------|------------------|------------------|
| | Total | Left | Right | Total | Left | Right | Total | Left | Right |
| Humerus | 28.77 \pm 1.77 | 28.53 \pm 1.78 | 28.89 \pm 1.75 | 17.86 \pm 1.95 | 17.38 \pm 1.69 | 18.26 \pm 2.08 | 16.31 \pm 2.27 | 15.66 \pm 2.18 | 16.81 \pm 2.22 |
| Radius | 22.94 \pm 2.15 | 22.2 \pm 1.73 | 23.71 \pm 2.3 | 10.22 \pm 1.12 | 10.28 \pm 1.15 | 10.15 \pm 1.11 | 13.03 \pm 1.68 | 12.87 \pm 1.55 | 13.19 \pm 1.81 |
| Ulna | 24.20 \pm 1.87 | 24.29 \pm 2.04 | 24.12 \pm 1.73 | 12.42 \pm 1.71 | 12.26 \pm 1.60 | 12.57 \pm 1.82 | 13.83 \pm 1.65 | 13.83 \pm 1.65 | 13.19 \pm 1.81 |

NF, nutrient foramina.

Table 2 Number of nutrient foramina in humerus, ulna and radius

| No. of NF | Humerus | | | | Radius | | | | Ulna | | | |
|-----------|---------|------|-------|----|--------|------|-------|-------|-------|------|-------|-------|
| | Right | Left | Total | % | Right | Left | Total | % | Right | Left | Total | % |
| 0 | 4 | – | 4 | 4 | – | 4 | 4 | 5 | 1 | 2 | 3 | 3.75 |
| 1 | 51 | 41 | 92 | 92 | 38 | 36 | 74 | 92.50 | 39 | 38 | 77 | 96.25 |
| 2 | 1 | 3 | 4 | 4 | 2 | – | 2 | 2.50 | – | – | – | – |

NF, nutrient foramina.

Table 3 Location of nutrient foramina in humerus, ulna and radius

| Bone | Humerus | | | Ulna | | | | Radius | | | | |
|----------------|---------|-----|----|-------|-------|-------|------|--------|-------|-------|----|--|
| | MB | AMS | PS | IB | AB | AS | PS | AB | MB | AS | PS | |
| Location of NF | | | | | | | | | | | | |
| Number | 32 | 67 | 1 | 8 | 9 | 59 | 1 | 6 | 17 | 53 | 4 | |
| Percentage | 32 | 67 | 1 | 10.38 | 11.68 | 76.62 | 1.29 | 7.5 | 21.25 | 66.25 | 5 | |

NF, nutrient foramina; MB: medial border, AMS: anteromedial surface, PS: posterior surface, IB: inter-osseous border, AS: anterior surface, PS: posterior surface, AB: anterior border.

Table 4 Classification of bones on the basis of foraminal index

| Foraminal index | Humerus | Ulna | Radius |
|-----------------------|---------|------------|-----------|
| Type I (<33.33%) | – | 18 (22.5) | 18 (22.5) |
| Type II (33.34–66.6%) | 90 (90) | 59 (73.75) | 58 (72.5) |
| Type III (>66.67) | 6 (6) | – | – |
| Not typed | 4 (4) | 3 (3.75) | 4 (5) |

Data in parentheses denote percentage.

that the direction of the NF is determined by the growing end of the bone and its growth should be at least twice the growth of the other end. Absence of NF in long bones is well known. In such cases, NF is absent and bones are supplied by periosteal arteries¹⁰. Knowing all these facts and anatomical details of NF is

important for surgeons involved in vascular graft procedures.

Out of 260 bones, 11 did not have NF and six had double NF. No correlation was observed between length and diameter of the bone with absence or duplication of NF ($P = 0.05$). Mean foraminal indexes for humerus, radius and ulna were 52.657, 34.36

and 36.52, respectively. Majority (76.92%) of bones had NF in the middle third of their shaft; whereas the distal third was a rare position. NF were also most commonly present in the anteromedial surface of the humerus (67%) and anterior surface of both radius (66.25%) and ulna (76.62%). The overall incidence of multiple NF was found to be less in our study (4%) as compared to earlier studies (8–40%) conducted in various populations by various researchers^{3–5,11–15}. Mysorekar³ has reported NF of the humerus to be in the medial border or in anteromedial surface in 80% of cases; in the present study, it was found to be in that location in 99% of cases. Position and number of NF in radii and ulna

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were found to be similar as observed in earlier studies^{3,4,13,14,16}.

As the majority of bones had a single NF and disruption of the nutrient artery present in it may lead to bone ischaemia, particularly in diaphysis, any surgical intervention in the humerus, radius or ulna should best leave the nutrient artery undisturbed. Fracture of the upper or lower third of the humerus, which is more common than the middle third, is less likely to jeopardise its blood supply, as NF is present most commonly in its middle third, i.e. distal to insertion of deltoid muscle. Nutrient artery of most bones enters through its middle third for the humerus in its medial border or anteromedial surface and in its anterior surface for radius and ulna. Thus, information can be used to precisely locate the nutrient artery in the majority but not all the bones, for procedures such as joint replacement therapy, fracture repair, bone grafts, reconstruction procedures and vascularised bone microsurgery.

The importance of pre-operative arteriography to precisely locate the nutrient artery before elective surgeries in which the artery is planned to be manipulated, e.g. arterial anastomosis for vascularised grafts, cannot, however, be overemphasised because in approximately 25% of cases, the location of NF was found to vary widely in diaphysis.

Conclusion

Most of dry bones that we studied had single NF, absence or duplication of NF had no correlation with length

or diameter of bone. All NF were directed towards the elbow. Classifying bone on the basis of NF revealed that most of these long bones were of type II. Except for the incidence of double NF, other findings of the present study are in accordance with similar studies conducted in the past by various others. However, this study also highlights the correlation between the incidence of NF and dimensions of bones. These population-specific findings can be of use for review by orthopaedic surgeons for planning surgeries in the region of the arm and forearm.

Abbreviations list

APD, anteroposterior diameter; FI, foraminal index; NF, nutrient foramen; TD, transverse diameter.

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