ANATOMICAL LANDMARKS FOR SAFE SURGICAL PRACTICE: A STUDY OF NUTRIENT FORAMINA OF DRIED CADAVERIC LONG BONES OF UPPER LIMB

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ABSTRACT

Background and objectives: The vascular supply of long bones through nutrient arteries entering via nutrient foramina, plays a crucial role in bone health and remodeling. Understanding the morphometric characteristics of nutrient foramina is essential in orthopedic, plastic, and reconstructive procedures for preventing complications such as delayed union, nonunion or avascular necrosis. The aim of the study was to evaluate the number, direction, location, position of nutrient foramina in long bones of the upper limb to provide anatomical data relevant to local surgical practices.

Methods: This descriptive, cross sectional study was conducted in the Department of Anatomy, King Edward Medical University, Lahore, from October 2024 to December 2024. A total of 150 dried cadaveric long bones of the upper limb were taken, including 50 humeri, 50 radii, and 50 ulnae. Nutrient foramina were examined for number, location, size, direction, and position. Bone length and distance of foramina from the proximal end were measured, and the Foramen Index (FI) was calculated. Data were analyzed using SPSS version 26.0.

Results: A single nutrient foramen was most common: 76% in humeri, 72% in radii, and 94% in ulnae. Double foramina were rare, and absence of foramina was observed in 20% of humeri, 24% of radii, and 4% of ulnae. In humeri, nutrient foramina were predominantly located on the anteromedial surface and classified as Type II (middle third) in 95% of cases. In radii and ulnae, most foramina were in the proximal third (Type I).

Conclusion: This study provided population-specific data on the morphology and topography of nutrient foramina, critical for optimizing surgical outcomes in orthopedic and reconstructive procedures by aiding in the identification of safe zones and preserving vascular integrity.

Key words: Nutrient foramen, foramen index, nutrient artery, long bones.

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The physiological function of long bones relies on their vascular supply primarily provided by nutrient arteries.[1] These arteries enter the bones through small anatomical openings called nutrient foramina usually located along the diaphysis.[2] According to general anatomical principles, nutrient foramina are usually directed towards the elbow in upper limb bones, i.e. downward in the humerus and upward in the radius and ulna.[3-4] The nutrient artery provides the main blood supply to the inner two-thirds of the cortex and the medullary cavity, contributing significantly to bone health, remodeling, and repair.[5]

The fractures of long bones are increasing day by day due to an increase in the number of road traffic accidents, various sports injuries and bony pathologies like osteoporosis leading to reduction in quality of life, productivity and financial earnings.[6] The humerus is mostly vulnerable during sports and automobile injuries, and overall, humeral fractures account for about 3% of all bone fractures in the human body.[7] A comprehensive understanding of the vascular anatomy of bones is essential for various orthopedic procedures such as open reduction and internal fixation (ORIF), bone grafting, intramedullary nailing, and lengthening of limbs.[8-9] The injury to nutrient artery during these procedures can affect the bone perfusion, subsequently leading to serious complications as delayed union,

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nonunion or avascular necrosis.[10]

In plastic and reconstructive surgeries, the anatomical knowledge of nutrient foramina is particularly important for vascularized bone grafts or osteo-cutaneous flaps harvested from the radius and ulna.[11] Saving the nutrient artery during radial forearm free flaps is vital for graft survival and reduction of postoperative complications.[12] During bone transplant surgeries, data on distribution of the nutrient foramina helps the surgeons in preserving the diaphyseal vascularization.[13] For medico-legal cases, morphometric characteristics of long bones play an important role as the distribution of nutrient foramina can vary with ethnicity, geography, age, and sex.[13]

Multiple studies around the globe have demonstrated the variations in the number, size, location and direction of nutrient foramina. Topographical anatomy varies among different populations. Local studies on topographic and morphometric characteristics of nutrient foramina are required not only academically but also for safe clinical practices in local population. The objective of this study was to evaluate the number, direction, location, position and distance of nutrient foramina in cadaveric long bones of upper limb from the Department of Anatomy at King Edward Medical University, Lahore, Pakistan with the aim of providing a database for surgeons, anatomists, and medical educators in Pakistan that can help them in the development of surgical guidelines.

METHODS

This descriptive cross-sectional study was conducted in the Department of Anatomy, King Edward Medical University, Lahore, from October 2024 to December 2024. Ethical approval was taken from the Institutional review board (IRB) of King Edward Medical University # 170/RC/KEMU. A total of 150 dried and cleaned cadaveric long bones of the upper limb were analyzed. These included 50 humeri, 50 radii, and 50 ulnae of both sides. Bones with fractures or any pathological abnormalities were excluded from the study. The age and sex of the bones were not determined. Each bone was examined macroscopically for the presence of nutrient foramina using a magnifying glass. Nutrient foramina were identified by the presence of a distinct groove and a slightly raised edge marking the beginning of the nutrient canal. The number, location, direction and position of nutrient foramina was observed. The location of the NF was determined by analyzing different borders and surfaces of each bone. The direction of the nutrient canal was established by passing a stiff wire through the foramen, towards the distal end in the humerus, and towards the proximal end in the radius and ulna.

The total length of each bone and the distance of the nutrient foramen from the proximal end were measured using an osteometric board. The Foramen Index (FI) was calculated by using Hughes formula as follows.

FI = (DNF/TL) x 100 where DNF=the distance of nutrient foramen from the proximal end of each bone, TL= total bone length.

Based on the FI, the position of the nutrient foramen was categorized as follows:

- Type I: FI < 33.33 (foramen located in the proximal third of the bone)
- Type II: FI = 33.33–66.66 (foramen located in the middle third
- Type III: FI > 66.66 (foramen located in the distal third)

Data were entered and analyzed using SPSS version 26.0. The number and location of nutrient foramina were presented as frequencies and percentages. Total bone length and distance of nutrient foramina from the proximal end, were expressed as means ± standard deviations. The Foramen Index was used to assess the relative position of each nutrient foramen.

RESULTS

A total of 150 long bones of the upper limb including 50 humeri, 50 radii, and 50 ulnae were studies from both sides. In the humeri nutrient foramina were absent in ten bones (20%), a single foramen was seen in thirty eight bones (76%) and double in two bones (4%). In the radii, 12(24%) of bones lacked nutrient foramina, 36(72%) had a single foramen, and 2(4%) showed double foramina. Among the ulnae only 2(4%) had no nutrient foramina while 47(94%) presented a single foramen and 1(2%) had double foramina. (Table-01) The location of nutrient foramina varied in different bones as shown in (Table-02). The total mean length of bones, distance of nutrient foramina from the proximal end and foramen index of each bone was calculated as shown in (table-03). Regarding position of nutrient foramina in the upper, middle or lower 1/3 of humeri, there was no type 1 foramina , type 2 in 38(95%) and type 3 in 2(5%). In the radii, type 1 foramina were observed in 27(71%), type 2 in 11(29%) with no type 3 foramina. Among the ulnae, type 1 foramina were seen in 20(42%), type 2 in 28(58%) and no type 3 foramina were observed. (Table-04)

Table 1: Number of nutrient foramina in long bones of upper limb.

Bones	Number of foramina	Number of bones (%)
Humerus (n=50)	0 1 2	10 (20) 38 (76) 2 (4)
Radius (n=50)	0 1 2	12 (24) 36 (72) 2 (4)
Ulna (n=50)	0 1 2	2 (4) 47 (94) 1 (2)

Table 2: Location of Nutrient Foramina in dry long bones of upper limb.

Bones	Location of N. F	Number Foramina n (%)
Humerus (N.F, n=42)	Anteromedial border Anteromedial surface Posterior surface	10 (23.8) 28 (66.6) 04 (9.5)
Radius (N.F, n=38)	Anterior Border Interosseus Border Anterior Surface Posterior Surface Lateral Surface	03 (7.9) 07 (18.4) 22 (57.8) 05 (13.2) 01 (2.6))
Ulna (N.F, n=49)	Interosseus Border Anterior Border Anterior Surface	12 (24.4) 03 (6.1) 34 (69.4)

Table 4: Position and direction of Nutrient Foramina.

Bones	Type 1		Type 2		Type 3	
	n	%	n	%	n	%
Humerus (n = 40)	00	00	38	95	02	5
Radius (n=38)	27	71	11	29	00	00
Ulna (n=48)	20	42	28	58	00	00

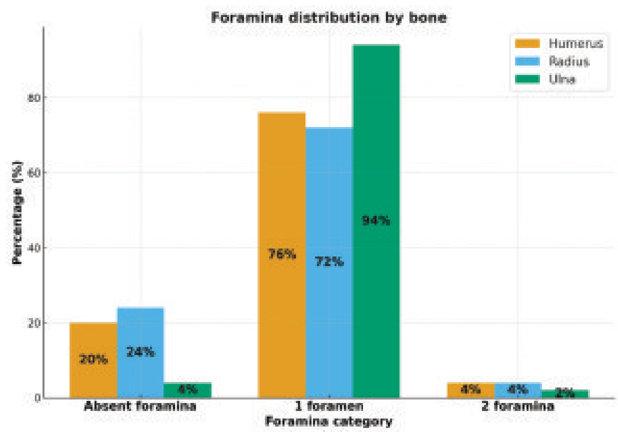

Figure 1: *Bar diagram showing distribution of foramina in different bones.*

Figure 2: *showing single and double nutrient foramina with their direction & location in Ulna.*

Table 3: Morphometric analysis of nutrient foramina in dry long bones of upper limb

Bones with Nutrient foramina	Parameters	Total Length (cm)	Distance of NF from proximal end (cm)	Foramen Index (%)
Humerus (n=40)	Mean Std. Deviation Minimum Maximum	31.15 2.42 27.50 37.30	17.55 2.60 11.20 24.30	56.42 7.30 37.21 67.37
Radius (n=38)	Mean Std. Deviation Minimum Maximum	24.4 1.35 21.80 27.50	8.04 1.05 5.70 11.20	32.82 3.84 23.27 42.26
Ulna (n=48)	Mean Std. Deviation Minimum Maximum	26.05 1.45 21.90 29.20	9.47 1.49 6.40 12.50	36.32 5.05 24.62 45.80

Figure 3: *Showing single and double nutrient foramina with their direction & location in radius.*

Figure 4: *Showing single and double nutrient foramina with their direction& location in humerus.*

DISCUSSION

The present study provides valuable morphometric and topographical data on the nutrient foramina of cadaveric long bones of the upper limb in the Pakistani population. These findings highlight anatomical features and underscore notable population-specific variations with important clinical implications. Given that nutrient arteries are the primary blood supply to long bones, entering through nutrient foramina, understanding their anatomical variability is essential in orthopedic, reconstructive, and forensic contexts.

Knowledge of these variations is particularly critical for plastic surgeons performing microvascular bone grafts, where preservation of vascular integrity is paramount to ensuring the survival of osteoblasts and osteocytes and promoting successful graft integration. The present study reinforces the predominance of a single nutrient foramen: 76% in the humerus, 72% in the radius, and 94% in the ulna. These findings are consistent with prior studies by Sreekanth and Hema[1], Kumar[2] and Pankaj et al.[3] who also reported a high frequency of single foramina, supporting established anatomical norms.

Nonetheless, anatomical variation does exist. Double foramina were identified in a small proportion of bones 4% in both the humerus and radius, and 2% in the ulna. These findings are in line with results from Mishra et al.[4] and Ghafoor et al.[11] who reported double foramina in fewer than 5–8% of bones. In contrast, Ukoha et al[14] observed a significantly higher incidence of double foramina (18%) in Nigerian humeri, suggesting possible ethnic or regional variation. Rare instances of triple foramina, such as those reported in the humerus by a study in Bihar[2] (1.25%), were not observed in the current sample.

The presence of double or triple foramina may be attributed to accessory nutrient arteries, possibly acting as compensatory mechanisms in response to developmental variations in the primary vascular supply.[15] Procedures such as fracture fixation, bone graft harvesting or intramedullary nailing can compromise intraosseous blood flow and delay bone healing.[16,17] Therefore, identifying the number and precise location of nutrient foramina is critical to minimizing intraoperative complications. In radiological and forensic applications, multiple foramina can also serve as valuable anatomical markers[18].

The absence of nutrient foramina was noted in 20% of humeri, 24% of radii, and 4% of ulnae. These rates are consistent with data from Sar et al.[8] and Ukoha et al.[14] who reported absence in 26% of Nigerian humeri and 32% of radii. The higher absence rate in the radius has important clinical implications, especially considering its frequent use in vascularized bone grafts such as radial forearm flaps.[19] Absence of a nutrient foramen in this bone could result in inadequate vascular supply, compromising graft viability and healing.[20] In contrast, the ulna demonstrated a relatively stable vascular pattern with a low absence rate, potentially contributing to favorable outcomes in ulnar fracture repair and reconstruction.[20]

Topographically, most humeral foramina in this study were located on the anteromedial surface (66.6%) followed by the anteromedial border (23.8%) and posterior surface (9.5%). These findings align with those reported by Asharani and Ningaiah[5] and Ghafoor et al.[11] Similarly, radial and ulnar foramina were most commonly found on the anterior surface and interosseous border, consistent with previous studies.[9,10] The location of the NF also influence choice of surgical technique to be used in particular surgical exposures especially in plating or intramedullary fixation. Adequate knowledge about the distribution of NF in long bones topographically also helps in in diagnosis and treatment of conditions relating to impaired bone healing and developmental pathologies.[21]

Regarding the direction of nutrient canals, this study found a distal direction in humeri and a proximal direction in both the radius and ulna. This pattern follows the classical anatomical rule: "towards the elbow we go, from the knee we flee," a directional consistency supported by Afzal et al.[12] Recognizing this orientation is vital in fracture fixation and bone grafting, as injury to nutrient arteries during surgery may significantly impair vascularity and delay healing.[22]

The Foramen Index indicated that humeral foramina were predominantly located in the middle third (95%), while those of the radius (71%) and ulna (42%) were mainly in the proximal third. These observations mirror those of Mishra et al.[4] and provide guidance for defining safe surgical corridors that preserve vascular integrity. As emphasized by Serrano et al.[6] preservation of the nutrient artery is critical for optimal outcomes in humeral shaft fractures. Similarly, in procedures such as radial forearm flaps, precise knowledge of foramina location enhances flap viability. Manjatika et al.[7] have further underscored the utility of foraminal variations in surgical anatomy and forensic identification across diverse ethnic groups. Anatomical information of the foraminal index and the direction of nutrient canal leading to NF, significantly improves the outcome and usefulness of surgical interventions and ensures protection of bone circulation.[22]

Despite its strengths, this study has certain limitations. The sex and age of the bones were not known, restricting the ability to correlate findings with demographic factors. Furthermore, as this was a single-center study, generalizability may be limited. Similar limitations have been acknowledged by Kumar et al.[2] and Sar et al.[9], who advocate for broader, multi-institutional research to develop robust, population-specific anatomical databases.

CONCLUSION

The anatomical knowledge of nutrient foramen in long bones helps us in identification of safe zones for surgical interventions. Understanding of the anatomical variations is essential for microsurgical techniques. These findings provide essential anatomical data to guide safe orthopedic and reconstructive procedures and highlight the importance of population-specific knowledge for optimizing surgical outcomes.

Ethical Approval:

Ethical approval was obtained from the King Edward Medical University, Lahore IRB No. 170 /RC/ KEMU dated 16-02-2021.

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Author's Contribution

Conceptualization study design	SK, AH, AZ, MQM
Data Acquisition	SK, AH, MQM, AZ
Data Analysis/ interpretation	MQM, AZ, FR, SK
Manuscript drafting	SK, AH, MQM, FR
Manuscript review	SK, AZ, FR, AH

All authors read and approved the final draft.

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