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Morphological Analysis of Nutrient Foramina in Dry Adult Human Humeri

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ABSTRACT

Background: The nutrient artery is the major blood supply of the humerus and it enters the nutrient foramen to supply the bone. With the knowledge of the location of the nutrient foramen of the humerus, surgeons can prevent damage to nutrient arteries. It has importance in orthopedic surgical procedures like joint replacement therapy, vascularized bone microsurgery, etc. During surgical procedures, the clinician should take precautions because fractures passing through the foraminal area heal slowly or do not heal at all.

Methods: A total of one hundred humeri were studied out of which fifty-one were on the left side and forty-nine were on the right side. The shaft of the humerus was divided into the following three zones- upper zone- upper one-third, middle zone- middle one-third, and lower zone- lower one-third. All humeri were observed and compared with the other studies for the number, direction, and location of nutrient foramen on the different surfaces, borders, and zones as mentioned above. The total percentages were calculated and compared with the total percentages of other studies done on the nutrient foramen of the humerus.

Results: The percentage of humeri with single nutrient foramen was highest, 75%. In 45.83 % of humeri, nutrient foramen was present on the medial border, and in 35.41 % on the anteromedial surface. In 63.54% of humeri, nutrient foramen was present in the middle zone, 29.16 % in the lower zone, and 7.29 % in the upper zone. Every observed nutrient foramen was directed distally. In the present study, 45.83 % of humeri had nutrient foramen on the medial border.

Conclusion: Based on the knowledge of the location of the nutrient foramen of the humerus, surgeons can prevent damage to nutrient arteries.

Key-words: Bone microsurgery, Nutrient artery, Nutrient foramen, Fracture repair bone graft, Humerus

INTRODUCTION

The humerus, derived from the Latin word for "shoulder," is the longest bone in the upper limb. It consists of a shaft and two expanded ends. The proximal end features a rounded head, along with anatomical and surgical necks, as well as the greater and lesser tubercles.

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Structurally, the shaft is cylindrical near the proximal end but transitions to a triangular shape in cross-section towards the distal end. The humerus forms the shoulder joint by articulating with the glenoid cavity of the scapula, while its distal end connects with the radius and ulna to form the elbow joint [1].

The primary blood supply to long bones is provided by the nutrient artery. One or more diaphyseal nutrient arteries penetrate the shaft at an angle through the nutrient foramen, which opens into the nutrient canal. In the humerus, this artery originates near the mid-upper arm and enters the nutrient canal close to the coracobrachialis muscle insertion. The nutrient foramen is oriented away from the bone's growing end. Within

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the canal, the artery does not branch but later splits into ascending and descending branches inside the medullary cavity, which further divide into smaller, helical branches near the endosteal surface. These endosteal vessels are particularly susceptible to damage during surgical procedures such as intramedullary nailing for fractures [2].

Understanding the precise location of the nutrient foramen in the humerus is crucial for surgeons, as it helps prevent damage to the nutrient artery or arteries, thereby reducing the risk of complications such as nonunion and delayed bone healing. This knowledge is particularly valuable in orthopedic procedures, including joint replacement, fracture repair, bone grafting, and vascularized bone microsurgery. Since fractures involving the foraminal region tend to heal slowly or may fail to heal altogether, clinicians must exercise caution during surgical interventions [3].

Several studies have been conducted to evaluate the variations in the number, direction, and location of nutrient foramina in the humerus. Bhojaraja *et al.* [3] reported that most humeri possess a single nutrient foramen, while a smaller percentage have two or more. Sukumar [4] observed that most foramina were located on the anteromedial surface of the bone. Similarly, Ghule *et al.* [5] and Rathwa and Chavda [6] emphasized the importance of identifying nutrient foramina for surgical applications. Studies by Chandrasekaran and Shanthi [7], Asharani and Ningaiah [8], and Kumari and Prasad [9] have also contributed to understanding the anatomical variations of the humerus.

Understanding the anatomical variations of the nutrient foramen is essential for surgeons and orthopedic specialists. Murlimanju *et al.* [10] analyzed the morphology and topography of nutrient foramina in the human upper limb and highlighted their significance in surgical planning. Other studies, such as those by Forriol *et al.* [11] and Shulman [12], further provide valuable insights into the vascular supply of long bones and its clinical relevance.

MATERIALS AND METHODS

Place of the study- The present study was performed on one hundred unpaired dry adult human humeri of undetermined gender as well as age from the bone library of the Department of Anatomy, Medical College, Mumbai. Out of the total available humeri, one hundred were selected by using the following inclusion and exclusion criteria.

Inclusion criteria- All dry adult human humeri of undetermined age and gender available during the study period

Exclusion criteria- Damaged bones, Bones affected due to any pathology, and bones of the pediatric age group were excluded.

Fig. 1: The single nutrient foramen on anteromedial surface

Fig. 2: The double nutrient foramina on medial border

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Fig. 3: Double nutrient foramina on posterior surface

Fig. 4: Single nutrient foramina on posterior surface

Research design- The shaft of humeri was divided into the following three zones- upper zone- upper one-third, middle zone middle one-third, lower zone- lower one-third. All humeri were observed and compared with the other studies for the number, direction, and location of nutrient foramen on the Anteromedial, anterolateral, and posterior surfaces, anterior, medial, and lateral borders, and different zones of the humerus as mentioned above. A total of one hundred humeri were studied out of which fifty-one were on the left side and forty-nine were on the right. Statistical analysis of the data was carried out to find out the percentages. The percentage obtained in the present study was compared with those found in the other studies performed on the nutrient foramen of the humerus.

Statistical Analysis- The percentage of humeri with single, double, or multiple nutrient foramina was calculated. The distribution of foramina across different surfaces, borders, and zones was evaluated and compared with previous studies. Microsoft Excel was used for data compilation and analysis.

RESULTS

A total of one hundred humeri were studied out of which fifty-one were of the left side and forty-nine were of the right side. Statistical analysis of the data was carried out to find out the percentages. In the present study, 75% of humeri had single nutrient foramen, 16% had double, and 5% consisted of three nutrient foramen, while in 4% of bones, it was absent (Table 1).

Table 1: Frequency and Distribution of Nutrient Foramina in the Humerus

Number of Nutrient Foramen	Number of Bones	Percentage (%)
1	75	75%
2	16	16%
3	05	5%
Absent	04	4%

Based on surfaces and border of the humerus, the maximum percentage of nutrient foramen was present on the medial border, 45.83% while in 1.04% of the humerus, nutrient foramen was present on the lateral border (Table 2).

Table 2: Location of nutrient foramen based on surfaces and borders

Surfaces and Borders	Number of Bones	Percentage (%)
Anteromedial surface	34	35.41
Anterolateral surface	04	4.17
Posterior surface	11	11.45
Medial border	44	45.83
Lateral border	01	1.04
Anterior border	02	2.08

Also, 63.54% of the humerus consist of a nutrient foramen in the middle zone of the humerus while the remaining humeri consist of a nutrient foramen in the upper and lower zone (Table 3).

Table 3: Location of nutrient foramen based on Zones

Zones	Number of Bones	Percentage (%)
Upper zone	07	7.29
Middle zone	61	63.54
Lower zone	28	29.16

In this study, every observed nutrient foramen was oriented distally (Table 4).

Table 4: Direction of Nutrient Foramen

Direction of nutrient foramen	Number of Bones	Percentage (%)
Distally	96	100
Proximally	00	00

DISCUSSION

The humerus receives its primary blood supply via the nutritional artery. Additionally, it receives its supply from the brachial and axillary arteries and their branches through the metaphyseal arteries and periosteal vessels. The inner half of the cortex and medulla of the humeral shaft are supplied by the nutritive artery, whereas the outer cortex is supplied by the periosteal and metaphyseal branches. The quantity, orientation, and position of nutritional foramen on the humerus' surfaces, borders, and three distinct zones were the subjects of this investigation.

The findings of the present study regarding the number of nutrient foramen are comparable with the studies done by Bhojaraja *et al.* [3] and Sukumar [4]. The study done by Ghule *et al.* [5] shows single nutrient foramen on all the humerus (Table 5).

Table 5: Number of nutrient foramen observed by different authors (%)

Authors	One	Two	Three	Four	Absent
Present study	75	16	4	1	4
Bhojaraja *et al.* [3]	77	18	2	-	3
Sukumar [4]	79.51	13.93	3.28	-	3.28
Ghule *et al.* [5]	100	0	0	-	-
Rathwa *et al.* [6]	94.12	6.39	0	-	-
Chandrasekaran *et al.* [7]	76.74	20.54	2.71	-	-
Asharani *et al.* [8]	87	11	-	-	2
Kumari *et al.* [9]	90.62	7.8	-	-	1.56

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Also, the findings regarding the location of nutrient foramen on the medial and lateral border are comparable with the studies done by Bhojaraja *et al.* [3] and on the posterior border are comparable with the studies done by Sukumar [4], Rathwa *et al.* [6] and Chandrasekaran *et al.* [7] (Table 6).

Table 6: Locations of nutrient foramen by different authors about surfaces and borders (%)

Authors	AB	MB	LB	AMS	ALS	PS
Present study	2.08	45.83	1.04	35.41	4.17	11.45
Bhojaraja *et al.* [3]	-	41.8	1.6	49.2	1.6	5.7-
Sukumar [4]	-	-	-	82.79	5.55	10.65
Ghule *et al.* [5]	-	12	-	84	-	4
Rathwa *et al.* [6]	9.72	-	-	73.61	8.33	8.33
Chandrasekaran *et al.* [7]	-	-	-	89.92	1.55	8.53
Asharani *et al.* [8]	2	57	3	43	-	3
Kumari *et al.* [9]	10.93	21.87	-	65.62	-	1.56

The percentages of nutrient foramen in the upper zone are comparable with the studies done by Sukumar [4] and Rathwa *et al.* [6]. The percentage of a nutrient foramen in the middle zone is less than the studies done by Sukumar [4], Ghule *et al.* [5], Rathwa *et al.* [6], Chandrasekaran *et al*. [7], Asharani *et al.* [8] and Kumari *et al.* [9]. Also, the percentages of nutrient foramen in the lower zone are more than in the above-mentioned studies. Also, the study done by Chandrasekaran S et al shows nutrient foramen in the middle and lower zones only (Table 7).

Table 7: Location of nutrient foramen by different authors about zones (%)

Authors	Upper zone	Middle zone	Lower zone
Present study	7.29	63.54	29.16
Bhojaraja *et al.* [3]	-	95.9	4.1
Sukumar [4]	9.02	85.24	5.74
Ghule *et al.* [5]	1	92	7
Rathwa *et al.* [6]	8.33	86.11	5.56
Chandrasekaran *et al.* [7]	0	86.43	13.57
Asharani *et al.* [8]	-	87	13
Kumari *et al.* [9]	-	81.25	18.75

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The knowledge of the number and location of nutrient foramina in the humerus is of great clinical importance in orthopedic and reconstructive surgeries. Variations in the number of foramina can affect the vascular supply to the bone, particularly during procedures such as intramedullary nailing and bone grafting. A study by Prashanth *et al.* [13] highlighted the role of nutrient arteries in maintaining bone viability post-fracture. The present study supports findings by Gümüsburun *et al.* [14], who reported that the majority of nutrient foramina are located on the anteromedial surface, aiding in surgical approaches. Additionally, Kumar *et al.* [15] emphasized that fractures occurring along the foraminal region often result in delayed healing due to compromised blood supply. These variations should be carefully considered by surgeons to minimize postoperative complications and enhance patient recovery.

CONCLUSIONS

Total 75% of humeri in the current study had a single nutritional foramen, 45% had one on the medial border, and all the nutrient foramina pointed distally. Surgeons can improve the results of surgical treatments by preventing injury to the nutrient artery or arteries by knowing the location, number, and direction of the humeral nutrient foramen. Additionally, it plays a significant role in orthopaedic surgical operations such as vascularised bone microsurgery, fracture repair bone grafts, and joint replacement therapy.

LIMITATIONS

The present study was done on one hundred dry adult human humeri of unknown age, gender, and ethnicity.

CONTRIBUTION OF AUTHORS

Research concept-Kavita S. Kokane, Vivek K. Hingmire
Research design- Vivek K. Hingmire, Nagaraja V. Pai
Supervision- Kavita S. Kokane, Vivek K. Hingmire
Materials- Vivek K. Hingmire, Nagaraja V. Pai
Data collection- Kavita S. Kokane, Vivek K. Hingmire
Data analysis and Interpretation-Kavita S. Kokane
Literature search- Kavita S. Kokane, Vivek K. Hingmire
Writing article- Kavita S. Kokane, Vivek K. Hingmire
Critical review- Vivek K. Hingmire, Nagaraja V. Pai
Article editing- Kavita S. Kokane, Vivek K. Hingmire
Final approval- Vivek K. Hingmire, Nagaraja V. Pai

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