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Original Research Article

Morphometric study of the diaphysial nutrient foramen of the humerus in the Indore population

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ABSTRACT

Background: The nutrient arteries may be affected to a consequence of fracture/surgical intervention of fracture of the humeral shaft, which may result in nonunion or delayed union of fracture. Number and position of nutrient arteries must be determined. In order to preserve them during any surgical procedure of the humeral shaft, it is therefore essential to be aware of the existence of the nutrient foramen. The primary objective of this research is to identify the number, location, and orientation of nutrient foramina (NF) of humerus.
Methods: The study was conducted on 100 dried humeri of unknown gender obtained from department of anatomy, Index Medical College, Indore (M.P), India. The number, location, and direction of NF were observed.
Results: One nutrient foramen was present in 77% of humeri, followed by double foramen in 20% of cases and triple foramen in 3% of cases. The anteromedial surface hosted the majority (80.16%) of the NF, followed by the anterolateral (4.76%) and posterior surfaces (15.08%). The middle third of the shaft (96.03%) included the greatest number of NF, followed by the distal third (3.97%). On the distal end of the humerus, there was no nutrient foramen to be observed. All NF were directed downward.
Conclusions: The location of the nutrient foramen of the humerus was not constant; it may present on anteromedial, anterolateral, or posterior surfaces. Similarly, it may present on the middle or distal third of the shaft of the humerus. This study will help surgeons planning the surgical intervention of the shaft of the humerus, which will possibly reduce the chances of nonunion or delayed union.

Keywords: Diaphysis, Foramen index, Nutrient artery, NF, Humerus

INTRODUCTION

Fractures of long bones are not uncommon in the modern era due to changes in lifestyle and dependency on machinery. The blood supply of long bones plays an important role in the healing of fractures.[1,2] Long bones derive their blood supply through the nutrient, periosteal, metaphyseal, and epiphyseal arteries. The medulla and inner half of the cortex of the shaft of long bones is supplied by the nutrient artery. In contrast, the outer cortex of the shaft and metaphysis are supplied by periosteal and metaphyseal arteries.[3] The nutrient artery enters the shaft through the nutrient foramen leading into the nutrient canal.[4] The site of entry of the nutrient artery is almost always constant and directed away from the growing end.[5] A nutrient foramen is located at the anteromedial surface in the middle one-third of the shaft of the humerus.[6] The nutrient artery enters through the nutrient foramen, which is a branch of the brachial artery.[7] It is the main source of blood supply to the humerus and is also important during the active growth period of the fetus and during the early phase of ossification [8]. The nutrient foramen of the humerus is directed toward the elbow. The location of NF varies and may change during growth in mammalian bones.[8] The knowledge of the location of the nutrient foramen is

important in operative procedures to preserve circulation.[9-11] The vascular system of bone is closely related to fracture healing and hematogenic osteomyelitis.[12] Detailed knowledge about the blood supply of long bones is important in the development of new transplantation and resection techniques in orthopedics. This study aimed to find out the number and location of the nutrient foramen in relation to different surfaces, and the site of the nutrient foramen in relation to different segments and directions of the nutrient foramen of the humerus in the population of Indore.

METHODS

The present study, an analytical type observational study, was done on 100 (59 right and 41 left) dry humeri of unknown sexes received from the department of anatomy at Index Medical College, Indore (M.P.), India, between March 2022, and May 2023. Malwanchl university ethics committee granted ethical authorization (letter number. MC/Resarch/EC/PhD/2021/161). This study did not include any damaged or healed fractured bones, congenital abnormalities/ severe pathological alterations. For each humerus, a side determination was made. The existence of a clearly defined groove leading to the foramen distinguished the NF apart from other foramina.

The instruments used were osteometric board, magnifying hand lens, measuring tape, scale and divider. Photographs were taken with the digital camera. All bones were closely observed for identifying NF with the help of hand-lens, so that small foramina would not be missed.

If the humerus has more than two NF, the foramen that is larger in size is called the dominant foramen, and the other is called the secondary foramen. The position of the nutrient foramen was determined by the foraminal index (FI) using the following formula.[13]

FI=DNF/TL×100.

Where DNF is the distance of nutrient foramen from the most proximal part of the humerus and TL is the total length of the humerus.

The position of the nutrient foramen was divided into three types according to FI: type 1=FI<33.33, where the foramen is located in the proximal third of the humerus; type 2=FI between 33.33 and 66.66, where the foramen is located in the middle third of the humerus; type 3=FI>66.66, where the foramen is located in the distal third of the humerus (Figure 1).

The total length of humeri was measured by an osteometric board in centimeters. The distance of nutrient foramen from the most proximal point of the humerus was measured by a digital vernier caliper in centimeters. All observations were tabulated and statistically analyzed using a Microsoft excel worksheet.

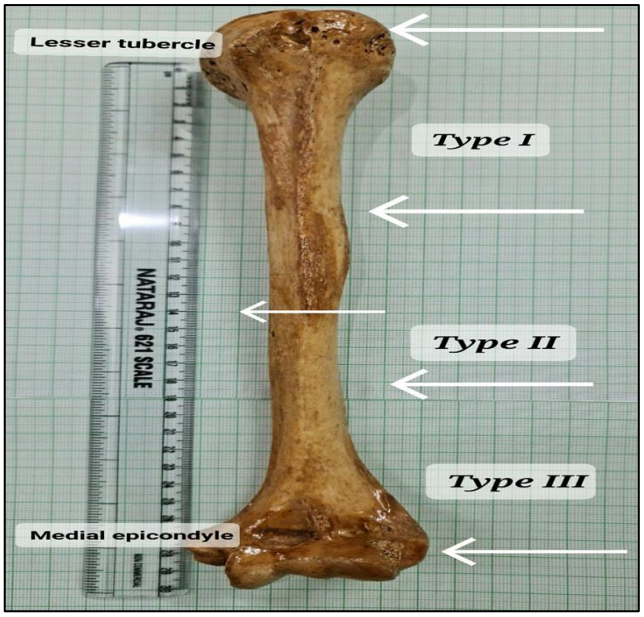

Figure 1: The range given is determined from foraminal index.

RESULTS

The incidence of the number of NF was observed and classified according to its presence or absence. The frequency of number of foramina was observed from one to three. Single nutrient foramen was observed in 41 (41%) of the right humerus, 36 (46%) of the left humerus, i.e., 77 (77%) of the total humerus. Two nutrient foramen were observed in 16 (16%) of the right humerus, 4 (4%) of the left humerus, and twenty (20%) of the total humerus. Three NF were observed in two (2%) of right humerus, one (1.0%) of the left humerus i.e., total of three (3%) humerus (Table 1 and Figures 2 and 3).

The proximal third, middle third, and distal third of the humerus' shaft were each defined in relation to the occurrence of NF. The middle third of the shaft, where there was the most nutrient foramen (96.03%), the distal one third had the second-highest number (3.97%) out of a total of 126 foramina. The proximal portion of the shaft lacked nutrient foramen. All of NF have been determined directed downward and towards the humerus' lower end, away from the developing end (Tables 2 and Figure 2).

It was discovered that the total mean length of the humeri was 30.07±1.89 cm in the right, 30.15±2.02 cm in the left and 30.11±1.94 cm overall. It was discovered that the average distance between the proximal end of the humerus and the nutritional foramen was 16.63±1.23 cm for the right, 16.66±1.22 cm for the left, and 16.65 ±1.22 cm for the entire humerus. The right, left, and overall humeri were found to have foraminal indices of 55.53%, 55.54%, and 55.53%, respectively (Table 3).

It has been observed that a total of 126 NF were observed and they were present on anteromedial, anterolateral, and

posterior surfaces. Out of 126 NF, 80.16% were present on the anteromedial surface, 79.75% on the right side, and 80.85% on the left side. Of the nutrient foramen, 4.76% were found on the anterolateral surface, out of which 5.06% were on the right and 4.25% were on the left side. The posterior surface had 15.08% of the nutrient foramen, out of which 15.19% were on right and 14.89% were on the left side. All NF were directed downward (Table 4 and Figures 2-4).

Table 1: Incidence of the number of the NF of the humerus.

Side and no. of humerus		Incidence of no. of nutrient foramen			
		Absent (0)	One (1)	Two (2)	Three (3)
Right	No. of humerus, (n=59)	-	41	16	02
	%	-	41	16	2
Left	No. of humerus, (n=41)	-	36	04	01
	%	-	36	4	1
Total	No. of humerus, (n=100)	-	77	20	03
	%	-	77	20	3

Table 2: Site of the NF in relation to different segments of the humerus.

Side of bone	Total no. of bone	Total no. of NF	Situation of foramen					
			Type-1 (proximal1/3)		Type-2 (midde1/3)		Type-3 (distal1/3)	
			N	%	N	%	N	%
Right	59	79	0	0	76	96.2	03	3.79
Left	41	47	0	0	45	95.74	02	4.26
Total	100	126	0	0	121	96.03	5	3.97

Table 3: The foraminal index, the length of humerus and distance between the NF and proximal end of humerus.

Parameter	Mean total length (cm)	Distance of NF from the proximal end (cm)	Foraminal index (%)
Right, (n=59)	30.07±1.89	16.63±1.23	55.53
Left, (n=41)	30.15±2.02	16.66±1.22	55.54
Total, (n=100)	30.11±1.94	16.65±1.22	55.53

Table 4: Location of the NF in relation to different surfaces of the humerus.

Side of humerus bone	Total no. of bone	Total no. of NF		Surface of humerus bone					
				Anteromedial		Posterior		Anterolateral	
		N	%	N	%	N	%	N	%
Right	59	79	100	63	79.75	12	15.19	04	5.06
Left	41	47	100	38	80.85	07	14.89	02	4.25
Total	100	126	100	101	80.16	19	15.08	06	4.76

Table 5: Comparison of the incidence of the number of the NF.

Authors	Year	N	Single NF, N (%)	Two NF, N (%)	Three NF, N (%)	Absent NF, N (%)
Laing et al[2]	1956	30	28 (93)	2 (7)	-	-
Carrol et al[14]	1963	71	48 (68)	20 (28)	3 (4)	-
Joshi et al[16]	2011	200	126 (63)	66 (33)	8 (4)	-
Halagatti et al[15]	2012	200	161 (80.5)	35 (17.5)	4 (2)	-
Chandrasekaran et al[3]	2013	258	198 (76.74)	53 (20.54)	7 (2.71)	-
Bhatnagar et al[21]	2014	70	63 (90)	5 (7.14)	1 (1.43)	1 (1.43)
Mansur et al[17]	2016	253	154 (60.87)	73 (28.85)	16 (6.32)	-
Asharani et al[18]	2016	120	104 (87)	20 (11)	-	2 (2)
Pankaj et al[19]	2017	350	283 (80.86)	47 (13.42)	1 (0.29)	19 (5.43)
RamyaSree et al[13]	2019	218	169 (81.19)	40 (18.35)	1 (0.45)	8 (3.67)
Ali[20]	2021	250	210 (84)	35 (14)	-	5 (2)
Arfan et al[4]	2022	86	52 (60.4)	25 (29.06)	5 (5.81)	4 (4.65)
Kumar et al[30]	2022	80	73 (91.25)	3 (3.75)	1 (1.25)	3 (3.75)
Present study	2023	100	77 (77)	20 (20)	3 (3)	-

Table 6: Comparison of the location of the nutrient foramen in relation to surface.

Authors	N	Anteromedial surface (%)	Posterior surface (%)	Anterolateral surface (%)
Chandrasekaran et al, 2013[3]	258	89.92	8.53	1.55
Khan et al, 2014[23]	75	96	2.67	1.33
Yaseen et al, 2014[12]	100	88.50	8.53	3.50
Mansur et al, 2016[17]	253	88.86	1.22	9.76
Kumar et al, 2022[30]	80	89.02	6.52	9.76
Present study	100	76.51	14.39	4.54

Table 7: Comparison of the site of the nutrient foramen in relation to the segment.

Authors	N	Proximal 1/3rd	Middle 1/3rd	Distal 1/3rd
Chandrasekaran et al, 2013[3]	258	-	86.43	13.42
Yaseen et al, 2014[12]	100	-	89	11
Mansur et al, 2016[17]	253	0.54	94.84	4.62
Pankaj et al, 2017[19]	350	0.53	97.63	1.84
Arfan et al, 2022[4]	86	4.87	91.46	3.65
Kumar et al, 2022[30]	80	-	86.58	13.42
Present study	100	-	96.03	3.97

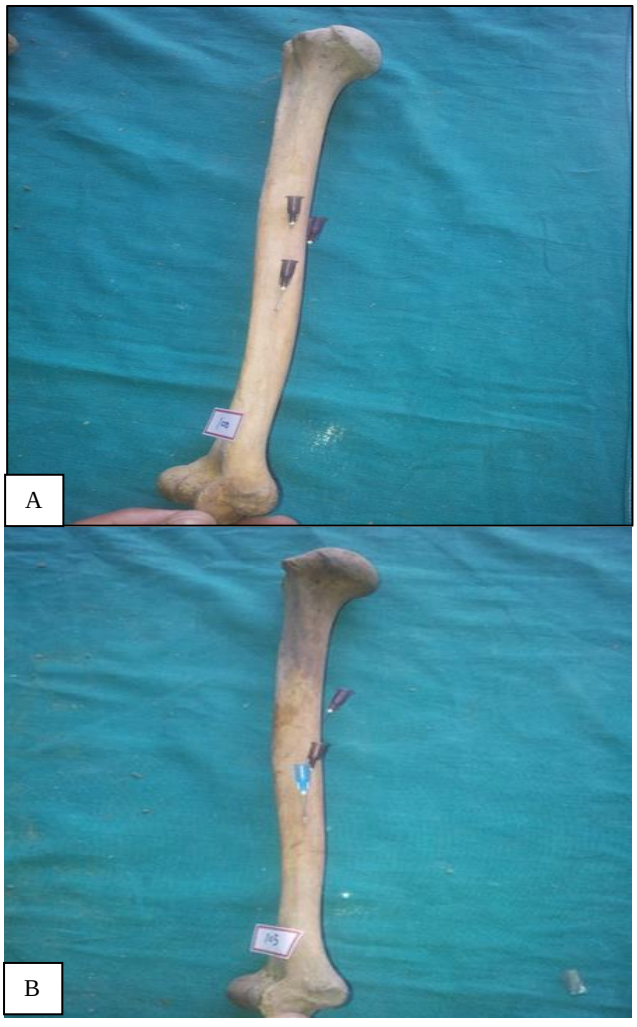

Figure 2: Three NF on the anteromedial surface; two is on the middle third and other one is on the distal third.

Figure 3: Two NF on the anteromedial surface; one is on middle third and other one is on distal third.

Figure 4: Nutrient foramen on the posterior surface.

DISCUSSION

The nutrition artery is a major supply of blood during active long bone development. Berard was the first person to link the direction of nutrition canal to the manner of ossification and bone development.[9] Thehumerus got blood supply from other sources as well, such as the metaphyseal and periosteal arteries, which are branches of the axillary and brachial arteries. The periosteal and metaphyseal arteries supply the outer cortex and metaphysis of the bone, but the nutritive artery supplies the inner half of the cortex and the medulla of the shaft. The investigation of the shaft's blood supply will aid in the understanding of fracture healing, delayed unions, and non-unions of the bone following fractures and bone transplants.[10]

The present study showed that single nutrient foramen was present in 77% of humeri. A similar finding was seen in studies by Chandrasekaran (76.74%)[3] and Halagatti etal (80.5%).[15] Many studies reported a lower incidence of single nutrient foramen. Joshi et al and Arfan et al reported single nutrient foramen only in 63% and 60.40% of humerus, respectively.[4,16] The present study showed that the prevalence of double nutrient foramen was found in 20% of humeri, which was very similar to the study done by Chandrasekaranv et al (20.54%) and Ramya et al (18.35%).[3,13] Joshi et al found a higher incidence of a double nutrient foramen in 33% of humeri.[16] Almost all authors observed the presence of triple NF in humeri.[14-16] The present study observed that triple nutrient foramen was found in 3% of humeri, which was very close to studies done by Chandrasekaran et al (2.71%) and Carrol et al (4%).[14] In this study, it has been observed that 0.0% of humeri did not have nutrient foramen, which the study was done by Pankaj et al who reported that in such cases, 5.43% of humeri are supplied by periosteal arteries (Table 5).[3,14,19,22]

The nutrient foramen is located on the anteromedial surface of the shaft of the humerus close to the medial border; however, its location may vary. In the present study, 80.16% of foramina were situated on the anteromedial surface, which was in accordance with the findings of Yaseen et al (88.50%) and Mansur et al (88.86%).[12,17] In contrast to this, a study done in the Pakistan by Khan et al reported a higher incidence (96%) of the NF situated on the anteromedial surface (Table 6).[23]

NF were also defined on the basis of their location in relation to various regions of the humerus. In the present study, 96.03% of NF were located inthe middle one-third of humeri followed by distal one-third in 3.97%. No NF were found on the proximal one-third of the humerus. This finding is in agreement with that of Pankaj et al (97.63%) and Mansur et al (94.84%) (Table 7).[17,19]

The nutrient artery is the main source of blood during the active growth of long bones. The correlation of the direction of the nutrient canal with the mode of ossification and growth of bone was first described by Berard.[24] The humerus also receives blood from metaphyseal and periosteal arteries, which are branches from the axillary and brachial arteries. The knowledge of variations of the NF is important for orthopedic surgeons who undertake the open reduction of fracture to avoid injury of nutrient artery thusdecreasing the chances of delayed union or nonunion of fracture.[16] The intact blood supply of bone is very important for the healing of a fractured bone.[25] It is well understood that delayed union or nonunion of fracture of bone occurs due to lack of arterial supply.[26,27]

In general, it was described that the vessels that invade ossifying cartilage are nutrient vessels, and the site is a nutrient foramen, accordingly the nutrient foramen is the actual location of the ossification center.[28]

The growing end of a typical long bone was used to establish the direction of NF, and it was assumed that the growing end developed twice as rapidly as the other end.[9] The position of NF may be affected by the expansion of two ends and remodelling.[8] Nagel described the hazards of intra-operative nutritional artery injury due to its exposure. It was stated that awareness of these foramina is useful in surgical techniques to protect the circulation.[29]

CONCLUSION

According to the findings of this study, the nutrient foramen of the humerus can also be located on the anterolateral and posterior sides in addition to the anteromedial surface. On the middle and distal parts of the humerus' shaft, nutrient foramen was discovered. Most of the humeri contained a single nutrient foramen, but there were also two or three foramina. Therefore, understanding the number, site, and direction of nutrient foramen will help orthopedic surgeons to avoid this area during internal fixation, fracture repair, bone graft, joint replacement surgery, and vascularized bone microsurgery to reduce the risk of damaging the nutrient artery. Damage to the nutrient artery may lead to the nonunion, delayed union or avascular necrosis of bone following fracture of the shaft of the humerus. The knowledge of nutrient arteries are equally significant to morphologists and clinical anatomists.

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