

Morphological and Topographical Anatomy of the Nutrient Foramen on 176 Humeri and Current Literature Review

Elif Bayraktar^{1,2} , Latif Sağlam^{1*} , Osman Coşkun¹ , Ahmet Ertas³ , Özcan Gayretli¹ 

¹ Department of Anatomy, Istanbul Faculty of Medicine, Istanbul University, Istanbul, Türkiye, elifbayraktar146@gmail.com, latif.saglam@istanbul.edu.tr, osmanc@istanbul.edu.tr, gayretli@istanbul.edu.tr, ror.org/03a5qrr21

² Department of Anatomy, Istanbul Faculty of Medicine, Institute of Graduate Studies in Health Sciences, Istanbul University, Istanbul, Türkiye, elifbayraktar146@gmail.com, ror.org/03a5qrr21

³ Specialist, Department of Anatomy, Cerrahpaşa Faculty of Medicine, Istanbul University-Cerrahpaşa, Istanbul, Türkiye, aertas@iuc.edu.tr, ror.org/01dzn5f42

* Corresponding Author

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Objective: The nutrient foramen of the humerus (NFH) is an important anatomical structure as it transports the nutrient artery that feeds the humerus. Our goal was to investigate morphological and morphometric features of the NFH.

Materials and Methods: In total, 176 (85 right, 91 left) dry adult human humeri were examined. We investigated the frequency, topographic position, and direction of NFHs. The distances of NFH to certain landmarks were also measured. Lastly, the foraminal index (FI) was determined.

Results: Humerus with one NFH and two NFHs were 151 (85.8%) and 22 (12.5%), respectively. NFHs were absent in 3 (1.7%) of humeri. All NFHs were downward. The mean shortest distances of the NFH to the most prominent point of the head of the humerus were found as 17.84 ± 2.64 cm in the humerus with a single NFH and 17.32 ± 2.76 cm in the humerus with a double NFH, respectively. The mean shortest distances of the NFH to the tip of the medial epicondyle were 11.39 ± 1.89 cm in the humerus with a single NFH and 13.01 ± 2.93 cm in the humerus with two NFHs. The overall average FI was 57%.

Conclusion: With this study, the distances of NFHs to certain landmarks were documented separately for single NFHs and double NFHs. Moreover, NFHs are most densely located in the middle third. We believe that this data may be helpful to orthopedic surgeons in terms of pre- and intraoperative planning and reaching NFHs more easily.

Keywords: Nutrient foramen of humerus, Nutrient artery, Topographic location, Foraminal index

1. INTRODUCTION

The humerus, the longest and largest bone of the upper extremity, is nourished mainly by the nutrient artery of the humerus (NAH). This artery reaches the humerus via the nutrient foramen of the humerus (NFH).¹

Like other nutrient arteries, the NAH is important in bone development during the prenatal and postnatal phases. It also encourages the development of a callus structure at the site of the fracture.² Insufficient blood flow at the fracture site may result in malunion or nonunion of the humerus.^{3,4}

Understanding the localization of NFH is crucial, as it can assist in optimizing invasive procedures involving NFH.⁵ The NFH is located near the attachment of the coracobrachialis muscle, posterior to the deltoid tuberosity, directed downward near the medial margin of the humerus, just inferior to the middle.¹

The anatomical features of the NFH are quite important in orthopedic surgery, bone grafting, and microsurgical bone transplantation on the humerus.⁶ Since the nature of vascularized grafts requires arterial anastomoses, NFH also plays an important role in such grafts.⁷

In this study, considering the clinical significance of NFH, our goal was to analyze the number, direction, topographic location, and distances of NFH to certain landmarks and to present its possible clinical interest.

2. MATERIAL AND METHODS

For this cross-sectional study, a total of 176 (85 right, 91 left) dry adult human humeri were examined from the Department of Anatomy, Istanbul Faculty of Medicine, Istanbul University. The exclusion criteria included: Bones exhibiting pathological deformities or damage. Bones originating from infants or children. Information on the gender, age, and race of these bones was not

accessible. The Clinical Research Ethical Committee of Istanbul Faculty of Medicine of Istanbul University approved the study (Date: 25/02/2022, number: 04).

2.1. Morphological properties

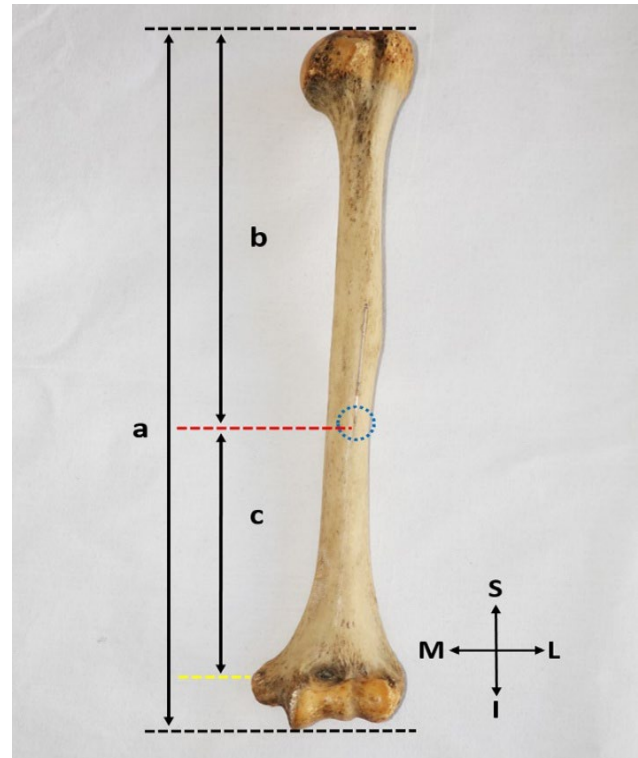
- The number of NFHs on the shaft of each sample was detected macroscopically.
- The patency and route of each NFH were explored by a 0.25 X 30 mm acupuncture needle. Foramina with diameters smaller than this needle were excluded from evaluation in the study.
- The topographic location of the NFHs was determined (On the border, surface, etc.).

2.2. Morphometric properties

- The perpendicular length between the highest point of the head of the humerus and its trochlea (Humerus length=**HL**) was evaluated (Figure 1).
- The perpendicular length from the highest point of the head of the humerus to the proximal margin of the NFH (**DHNF**) was measured (Figure 1).
- The minimum distance from the tip of the medial epicondyle to the distal edge of the NFH (**DMeNF**) was assessed (Figure 1).

Figure 1.

Demonstration of the measurement of the length of the humerus and distances of nutrient foramen to certain landmarks, anterior view, left. a: length of the humerus, b: the shortest distance of the nutrient foramen to the most proximal point of the head of the humerus, c: the shortest distance of the nutrient foramen to the tip of the medial epicondyle. The dotted black lines represent lines drawn parallel to the upper and lower ends of the humerus. The dotted yellow line represents the parallel line passing over the nutrient foramen. The dotted round blue line indicates the nutrient foramen.



S: Superior; I: Inferior; L: Lateral; M: Medial.

Lastly, we used the following calculation to obtain the foraminal index (FI): $FI = (DHNF / HL) \times 100$.⁸

According to the result of FI, the location of NF was classified into the following 3 groups:

Type 1: FI below 33.33%, proximal third of the humerus.

Type 2: FI between 33.33% and 66.66%, middle third of the humerus.

Type 3: FI above 66.66, distal third of the humerus.

The distances were measured with a digital caliper accurate to 0.01 mm (INSIZE Co., Ltd., Taiwan). Two independent researchers conducted

the measurements, and the final results were tabulated as the average value for each parameter.

3. RESULTS

3.1. Morphological properties

In a total of 176 bones, we examined, 151 humeri (85.8%) with a single NFH (Figure 2A), 22 of them (12.5%) with double NFH (Figure 2B), whereas 3 (1.7%) of them had no NFH. All NFHs were towards the elbow (Figure 2). The detailed distribution of NFHs according to the side is shown in Table 1.

Figure 2.

Demonstration of the number of nutrient foramen on humeri. A Single nutrient foramen, anterior view, left. B double nutrient foramen, anterior view, right. The dotted round blue lines indicate the nutrient foramen



S: Superior; I: Inferior; L: Lateral; M: Medial.

Table 1.

Distribution of the nutrient foramen of the humerus in terms of side

Number of NFH	Right, n (%)	Left, n (%)	Total, n (%)
Absent	2 (2.4%)	1 (1.1%)	3 (1.7%)
Single	75 (88.2%)	76 (83.5%)	151 (85.8%)
Double	8 (9.4%)	14 (15.4%)	22 (12.5%)
Total	85 (100%)	91 (100%)	176 (100%)

NFH: Nutrient foramen of the humerus

Most of the NFHs (59.4%, 116 NFHs) were located on the anteromedial surface of the humerus (Figure 3A). This was followed by the medial border (25.7%, 50 NFHs) (Figure 3D), lateral border (6.7%, 13 NFHs) (Figure 3F), anterolateral surface (4.6%, 9 NFH) (Figure 3C),

posterior surface (3.1%, 6 NFHs) (Figure 3B), and anterior border (0.5%, 1 NFH) (Figure 3E), respectively. The detailed topographic distribution of NFHs according to the side is shown in Table 2.

Table 2.

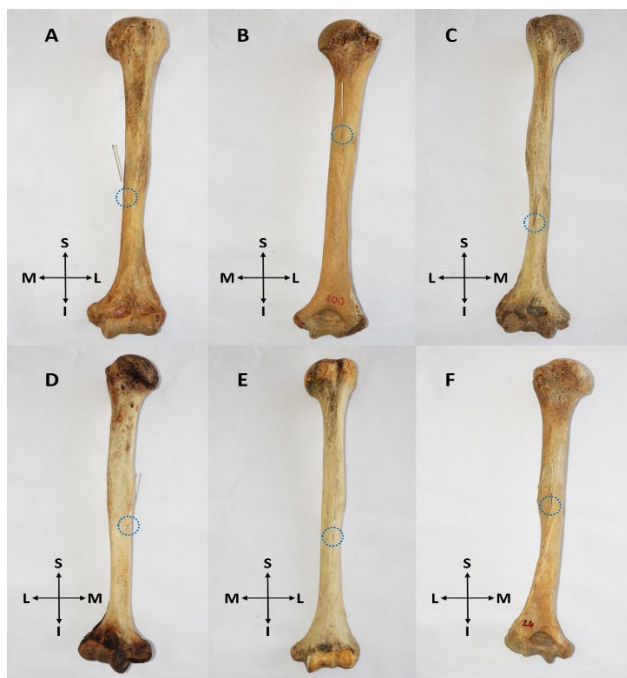
The topographic distribution of nutrient foramen of the humerus in terms of side

Location of NFH	Right, n (%)	Left, n (%)	Total, n (%)
AMS	52 (57.1%)	64 (61.6%)	116 (59.4%)
ALS	4 (4.4%)	5 (4.9%)	9 (4.6%)
PS	4 (4.4%)	2 (1.8%)	6 (3.1%)
AB	-	1 (0.9%)	1 (0.5%)
MB	24 (26.4%)	26 (25%)	50 (25.7%)
LB	7 (7.7%)	6 (5.8%)	13 (6.7%)
Total	91 (100%)	104 (100%)	195 (100%)

NFH: Nutrient foramen of the humerus, AMS: Anteromedial surface, ALS: Anterolateral surface, PS: Posterior surface, AB: Anterior border, MB: Medial border, LB: Lateral border.

Figure 3.

The illustration of nutrient foramen located in various topographic locations. A nutrient foramen on the anteromedial surface, anterior view, left. B, nutrient foramen on the posterior surface, posterior view, right. C, nutrient foramen on the anterolateral surface, anterior view, right. D, nutrient foramen on the medial border, anterior view, right. E, nutrient foramen on the anterior border, anterior view, left. F, nutrient foramen on the lateral border, posterior view, left. The dotted round blue lines indicate the nutrient foramen



S: Superior; I: Inferior; L: Lateral; M: Medial.

3.2. Morphometric properties

The HL was meanly 31.13 ± 2.71 cm (ranging from 24.71 to 47.79 cm) and the mean DHNF was found as 17.84 ± 2.64 cm in 151 humerus with single NFHs, while it was meanly 17.32 ± 2.76 cm in 22 humerus with a double NFHs. Similarly, the mean DMeNF was 11.39 ± 1.89 cm in 151 humerus with single NFHs, while it was meanly 13.01 ± 2.93 cm in 22 humerus with double NFHs.

Lastly, the overall mean FI was 57%. Also, the average FI was 57.7% (151 NFHs) in the humeri with 1 NFH and 54.6% (22 NFHs) in those with 2 NFHs. Moreover, 1.2% (2 NFHs) of NFHs were obtained as Type 1, 95.9% (166 NFHs) of NFHs were Type 2, and 2.9% (5 NFHs) of NFHs were Type 3. The FI regarding the NFHs is shown in Table 3.

Table 3.*Classification of nutrient foramen of the humerus according to foraminal index*

FI	Right (n=83), n (%)	Left (n=90), n (%)	Total (n=173), n (%)
Type I (<33.33%)	1 (1.2%)	1 (1.1%)	2 (1.2%)
Type II (33.33%-66.66%)	77 (92.8%)	89 (98.9%)	166 (95.9%)
Type III (>66.66)	5 (6%)	0 (0%)	5 (2.9%)

FI: Foraminal index

4. DISCUSSION

4.1. Morphological properties

For the number of NFHs, researchers reported different frequencies of NFHs. While studies report that there are no NFHs⁹⁻¹¹, there are also studies that have reported 1, 2, 3, 4, or even 5 NFHs.⁹⁻¹³ A brief current literature review is shown in appendix. With the current paper, a total of 176 bones were examined, 151 of them (85.8%) with a single NFH (Figure 2a), 22 of them (12.5%) with double NFHs (Figure 2b), whereas 3 (1.7%) of them had no NFH. Our results are compatible with the results of Asharani and Ningaiah.⁹

Previous reports agree that the direction of NFHs was toward the elbow.^{12, 14-16} Similarly, most of the NFHs observed in their study were on the anteromedial surface of the humerus. This rate was stated as the highest (90.83%, 109) in their research by Ukoha et al.¹⁷ while the lowest (39.99%) was reported by Asharani and Ningaiah.⁹ In our study, all NFHs were towards the elbow (Figure 2). In addition, most of the NFHs (59.4%, 116 NFHs) were on the anteromedial surface of the humerus. This was followed by the medial border (25.7%, 50 NFHs), lateral border (6.7%, 13 NFHs), anterolateral surface (4.6%, 9 NFHs), posterior surface (3.1%, 6 NFHs), and anterior border (0.5%, 1 NFH), respectively. The prevalence of NFHs on the anteromedial surface, recorded at 59.4% (116 NFHs), closely aligns with the findings of the studies conducted by Cihan and Toma.¹³ Nevertheless, our findings regarding NFHs on the medial border (25.7%, 50 NFHs) do not align with those reported in previous studies.^{9, 12, 17, 18} Our NFHs on the lateral border (6.7%, 13 NFHs) are inconsistent with the previous reports.^{9, 12} Our NFHs on the anterolateral surface (4.6%, 9 NFHs), and posterior surface (3.1%, 6 NFHs) are

almost the same as the studies of Mansur et al.¹¹ and Asharani and Ningaiah⁹, respectively. The NFHs in this study located on the anterior border (0.5%, 1 NFHs) are the lowest rate in the literature tabulated in the appendix.

4.2. Morphometric properties

In their studies conducted on 100 (56 right and 44 left) humeri, Solanke et al.⁷ reported that the mean HL was 28.77 ± 1.77 cm (28.89 ± 1.75 cm on the right side and 28.53 ± 1.78 cm on the left side). They also stated that the mean DHNF was 17.70 ± 2.12 cm. Güner et al.¹⁰ studied on 50 humeri. They found the mean HL was 310.2 mm and the mean DHNF was 175.5 mm. In addition, the FI was 55.7%. Mansur et al.¹¹ examined 253 (108 right and 145 left) humeri and they reported the mean HL was 270.22 mm (270.56 mm on the right side and 269.97 mm on the left side). The mean DHNF was 149.71 mm and the FI was 55.20% in their study. Ruthwik et al.¹² studied 80 humeri (42 right and 38 left). In their study, the mean HL was 299.5 mm (300.04 mm on the right side and 298.60 mm on the left side) and the mean DHNF was 154.24 mm (150.62 mm right and 157.66 mm on the left humeri). They also obtained an FI of 51.50%. In their observational study, Cihan and Toma¹³ studied 103 humeri (52 right and 51 left) and stated that the mean HL was 304.39 ± 20.04 mm on the right side and 303.54 ± 20.22 mm on the left side. Additionally, they reported that the mean DHNF was 172.49 ± 23.17 mm on the right side and 166.68 ± 25.26 mm on the left side. They calculated the mean FI as 55.77 and obtained no statistically significant difference in said values.

In our study, the mean HL was 31.13 ± 2.71 cm (ranging from 24.71 to 47.79 cm). Additionally, the mean DHNF was 17.84 ± 2.64 cm in 151

humerus with single NFHs and 17.32 ± 2.76 cm in 22 humerus with double NFHs. Similarly, the mean DMeNF was 11.39 ± 1.89 cm in 151 humerus with a single NFH and 13.01 ± 2.93 cm in 22 humerus with double NFHs. Our FI was meanly 57% and the average FI was 57.7% (151 NFs) in the humeri with 1 NFH and 54.6% (22 NFHs) in those with 2 NFHs. Our results for HL and DHNF align well with the findings of Güner et al.¹⁰ Regarding the DMeNF, Carroll¹⁹ examined 71 humeri and they found this value 13.7 cm (range 8.1-20.2 cm). Our DMeNF with a single NFH is close to Carroll's study and our DMeNF with double NFHs is consistent with Carroll's study. The FI in the present study is slightly higher than the previous reports.^{7, 10-13}

Solanke et al.⁷ observed only Type 2 (90%) and Type 3 (6%) NFH. Asharani and Ningaiah⁹ reported that 78.8% of the NFHs were located in the middle 1/3rd, 19.7% at the junction between the middle 1/3rd and lower 1/3rd, and 1.5 % in the lower 1/3rd. Mansur et al.¹¹ recorded that the NFHs were located at Zone II (middle 1/3rd=Type II) (94.84%), Zone III (lower 1/3rd=Type 1) (4.62%), and Zone I (upper 1/3rd=Type 3) (0.54%). Similar to Asharani and Ningaiah⁹, Khandve and Verma²⁰ reported that 79% of the NFHs were in the middle 1/3rd, 19.3% at the junction between middle 1/3rd and lower 1/3rd and 1.7% in the lower 1/3rd. Rathwa and Chavda¹⁶ stated that the NFHs were located at Zone II (middle 1/3rd=Type II) (86.11%), Zone I (upper 1/3rd=Type 1) (8.33%), and Zone III (lower 1/3rd=Type 3) (5.56%). Ruthwick et al.¹² observed that 90.09% of NFHs were in Zone 2 (middle 1/3rd=Type II), 8.08% in Zone 3 (lower 1/3rd=Type 3), and 1.01% in Zone 1 (upper 1/3rd=Type 1). A recent study by Cihan and Toma¹³ reported that 89.3% and 10.6% of the NFHs were located at the middle 1/3rd (Type II) and lower 1/3rd (Type 3) of the humerus, respectively. In the current paper, 95.9% of NFHs were Type 2, 2.9% of NFHs were Type 3, and 1.2% of NFHs were obtained as Type 1. Only Type 1 value in our study is consistent with Ruthwick et al.'s study.¹² Type 2 and Type 3 are higher than the previous studies which may be caused by different sample sizes.

4.3. Clinical importance

The humerus is the bone that has the highest blood supply among the upper extremity bones. The NAH which mainly nourishes the humerus arises from the deep brachial artery, additionally, branches of the axillary, radial, and ulnar arteries supply the humerus.²¹ Blood flow to the bones is crucial to their fracture healing. Despite optimal treatment, poor blood supply to the bone can lead to delayed fracture healing.^{3,9} For this reason, comprehending the detailed anatomical attributes of the NFH is crucial, given that it is the location where the arteries that nourish the humerus penetrate the bone. In our study, the number and direction of NFHs are consistent with previous studies, however they differ in topographic location. Our NFHs on the medial border are lower than the previous reports and the NFHs on the lateral border are higher than the previous ones. Similarly, the NFHs in our research located on the anterior border are the lowest rate in the literature. According to our results, NFHs are more frequently localized on the lateral border of the humerus. We believe that knowing this information may be helpful to surgeons in terms of pre- and intraoperative planning and reaching NFH more easily. In addition, our morphometric values are almost the same as in previous studies. Type 2 (95.9%) and Type 3 (2.9%) are higher than the previous research. That is, NFHs are most densely located in the middle third (Type 2) and less densely located in the distal third (Type 3) of the humerus. We emphasize the importance of this information for orthopedic surgeons, as it may aid in achieving easier access to NFHs. Thus, NFHs may be reached without delay, and complications such as bleeding may be minimized. Due to our results being generally consistent with previous studies performed in different regions, we believe that regional differences (geographical differences) are not essential for NFHs of the humerus. Unlike previous studies, in this study, we calculated the values of the humerus with single NFH and double NFHs separately. In orthopedic surgery, knowledge of the anatomical features of NFHs during the surgery of humeral bone graft and microsurgical bone transplantation is very important.⁶ In addition, knowing the exact

location of the NFH plays an important role in the success of vascularized bone grafts and joint allografts.^{6,7} Collectively, we believe that our findings may be important in the related invasive procedures to NFHs.

This study has several limitations. Although the sample size has been relatively larger than most previous studies, comparison statistics could not be performed because the humeri did not belong same person. Additionally, since we did not have age and gender records of the humerus samples, detailed statistical analysis could not be performed.²² Lastly, we did not have the clinical presentation of the said samples. Therefore, we did not make any comment on this topic.

5. Conclusion

It is essential to elucidate all anatomical aspects of NFHs. In this study, NFHs were analyzed anatomically. Many of our findings affirm previous studies and this study presents several additional findings regarding NFHs. Unlike earlier reports, in this study, morphometric values related to NFHs were documented separately for the humerus with single NFH and double NFHs. According to our results, NFHs were most densely located in the middle third and less densely in the distal third.

Article Information Form

Authors' Contribution

Conception: EB, LS, AE. Data collection: EB, ÖG, AE. Supervision: ÖG, LS, OC. Analysis or Interpretation: LS, EB, OC. Writer: LS, EB, OC. Critical Review: ÖG, OC.

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by authors.

The Declaration of Ethics Committee Approval

The study was approved by the Clinical Research Ethical Committee of Istanbul Faculty of Medicine of Istanbul University approved the study (Decision no: 04, Date: 25.02.2022).

Artificial Intelligence Statement

No artificial intelligence tools were used while writing this article.

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