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Indian Journal of Clinical Anatomy and Physiology

Journal homepage: https://www.ijcap.org/

Original Research Article

A morphometric study on variations of nutrient foramen of humerus with its clinical implication

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A R T I C L E I N F O

Article history:
Received 22-10-2021
Accepted 02-12-2021
Available online 01-03-2022

Keywords:
Foraminal index
Fracture
Humerus
Length
Location
Nutrient foramen
Nutrient artery
Osteometric board

A B S T R A C T

Background: Nutrient foramen is an opening in the shaft of the humerus, which is the point of entry of nutrient artery that supplies the medullary cavity. It plays an important role in healing of fracture.

Objective: To determine number, location with respect to the surfaces and the zones, direction of entry, the size and distance of nutrient foramen from distal ends and from the midpoint of humerus, the length of humerus.

Materials and Methods: 86 dried bones were taken, measurements of the bone were taken by using digital sliding caliper except the total length of humerus which was measured by using an osteometric board. In this analytical study the data was noted and the statistical analysis was done by using the mean range and standard deviation.

Observation: The humeri had one foramen in most specimen which were mainly noted on the anteromedial surface and medial border. The mean diameter was 0.814±0.213. The foraminal index had a mean value of 56.835±7.802%. The Landmark index had a mean value of 56.299±7.750%.

Conclusion: Our study provides details about the nutrient foramina that will benefit clinicians in surgical procedures, Orthopedic procedures like bone grafting and in plastic and reconstructive surgery.

1. Introduction

Humerus is the largest and the longest bone of the upper limb. The nutrient foramen is an opening in the shaft of the bone which allows passage of blood vessels to the medullary cavity of the bone for its nourishment and growth.[1] Trauma or surgical dissection may cause an insult to the nutrient foramen and lead to devascularization.[2] The fractures of the long bones are increasing in the number, because of industrial and traffic accidents, sports injury and pathological fractures in osteoporotic victims.[3] This knowledge of nutrient foramen was of tremendous significance to orthopedic surgeons performing procedures involving bone grafts, fracture repair, joint replacement and vascularized bone microsurgery.[4] One end of limb bones grows faster than the other.Because of this reason the direction of the nutrient foramen is directed towards the elbow in upper limb.[5]

The complications like delayed union or a non-union of the fracture may result when the blood supply is not established well.The medullary arterial system plays an important role in revascularization of the necrosing cortex and the uniting callus of the fracture site.[6] These complications can be minimized by having knowledge on the location of nutrient foramen and the relevant anatomy. With this knowledge the surgeon can prevent damage to the nutrient artery and minimize the complication of a delayed union or a non-union of the fracture.[7] Many scholars and researchers have studied the nutrient Foramina of the long bones. Most of these studies were performed years ago and

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https://doi.org/10.18231/j.ijcap.2022.008

very few in the recent times. They were not very specific about the humerus length. They discussed only about the number, direction and location of the nutrient foramina. Anatomical features can be identified by palpable landmarks in clinical practice. A palpable landmark for the nutrient foramina has not been described in the literature.[2]

In this study, we systematically have noted and observed the anatomical features of the nutrient foramina in the diaphysis of Humerus. We have analyzed the findings in our data and have conclusive comparison and descriptive interpretations of a few previously published studies on the same topic. Our study aims at analyzing the nutrient foramen in dry adult humeri, with regards to the number, location of the nutrient foramen with respect to the surfaces and zones and its distance from the mid-point of the humerus; our study also provides novel data, including the diameter and symmetry analysis of the nutrient foramen through which we also understand variation of length.

2. Materials and Methods

Our study was guided by findings from many previous studies. The present study consisted of 86 (40 right and 46 left side) dried and cleaned humerus which were taken from 1st year students and from the Department of Anatomy, TOMCH & RC. The bones which were damaged and those which had any pathological abnormalities were excluded.

The side determination was done for every humerus. Each humerus was numbered to avoid confusion and nutrient foramen was observed and studied carefully under proper illumination. The following parameters were noted; a) number of nutrient foramen b) location of the nutrient foramen with respect to the surfaces and the zones, c) direction of entry d) the size of the nutrient foramen e) the length of the humerus and f) the distance of the nutrient foramen from distal ends and from the mid-point of the humerus were analyzed. Determination of the total length of the individual humerus was taken as the distance between the superior aspect of the head and the most distal aspect of the trochlea of each humerii in millimeter.

Further, the humerus bone was divided into three equal zones as Zone 1(upper 1/3rd), Zone 2 (middle 1/3rd) and Zone 3 (lower 1/3rd) which was calculated by using an osteometric board. The mid-point of the humerus was also calculated by the same instrument. The nutrient foramina was distinguished by the presence of a well-marked groove leading to the foramen and by a well-marked often slightly raised edge of the foramen at the commencement of the canals shown in Figure 1.

This was reconfirmed using a biconvex lens under proper illumination. In ambiguous cases, we passed a fine needle through the foramen to confirm that it indeed enters the medullary cavity, as shown in Figure 2. Measurements of all the found nutrient foramina on each limb were noted and calculated. The nutrient foramen with the largest diameter was considered the dominant foramen and was considered in further statistical data as shown in Figure 3. The diameters of the nutrient foramina were measured using a digital sliding caliper that was accurate to 0.01mm.

Fig. 1: A specimen with a clear presence of nutrient foramen

Fig. 2: A needle being inserted into the foraman

Fig. 3: A specimen with presence of 2 nutrient foramina

Each bone was divided into 6 possible locations in relation to surfaces of the humerus. They are anteromedial surface (AMS), anterolateral surface(ALS), posterior surface (PS), medial border (MB), lateral border(LB) and anterior border (AB).

We calculated two indices, I1 and I2 to have a more comparative and comprehensive study. I1{Foramina index}was calculated based on Hughes methodology and formula I1=(DF/TL)*100, where DF is the distance from the distal most end of the bone to the nutrient foramen, and TL is the total length of humerus. Whereas I2 {Landmark index} was calculated based on Xue Z's methodology and formula, I2=(DNF/TL)*100, where DNF is the distance from the inferior surface of the medial epicondyle to the nutrient foramen.

Variation in distance of the nutrient foramen from the mid-point of the humerus was also noted. All calculation was performed on WD-220MS-BU model Casio calculator twice, 1) while data recording and 2) while reviewing to eliminate possibilities of errors.

3. Results

The following observations were found in our study.

3.1. Total length of the humerus

The mean total length was 304.220±21.986 mm (range 252-364mm).

3.2. Location of foramina

It has been observed that total of 116 number of nutrient foramina were found to be present on all humerii in relation to the surfaces, as shown in Table 2.

3.3. Direction of foramina

The direction of nutrient foramina was not showing any deviation from normal anatomical feature even in single case in this study. All the foramina were directed downwards or to the distal end of the humerus.

3.4. Size of the foramina

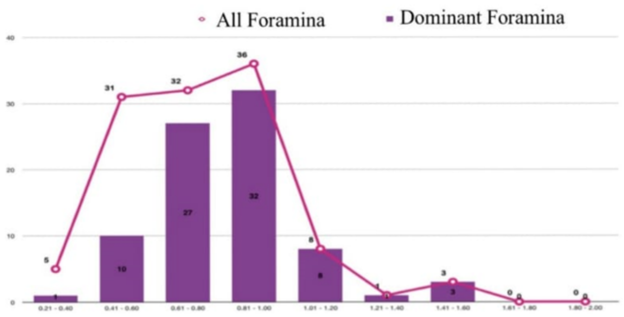
The mean foramen diameter was found to be 0.814±0.213 mm (range 0.33-1.48mm); on reviewing the data, most humerii have their dominant foramen ranging from size 0.60-1.00 mm as shown in Graph 1. The Line Graph represents all foramina and the Bar Graph represents dominant foramina.

3.5. The foramina index and the landmark index

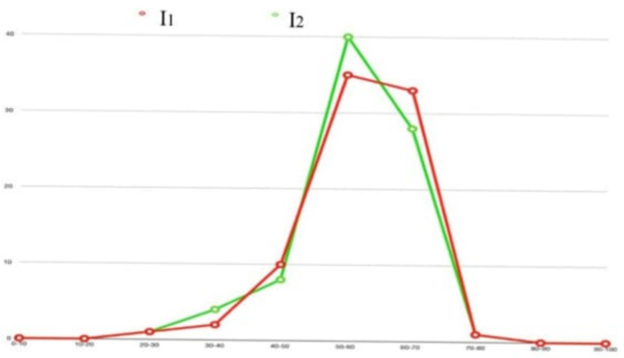
I1 (Foramina Index) had a mean value of 56.835±7.802% (range 29.71% - 72.64%); while the I2 (Landmark Index) had a mean value of 56.299±7.750% (range 29.51% - 72.03%). I1 is shown by the green line and I2 is shown by the red line in Graph 2.

Table 1: Number of foramina in humerii (n=86)

Number of foramina	Number of Humerii (n)	Percentage
1	52	60.40%
2	25	29.06%
3	5	5.81%
0	4	4.65%



Graph 1: Showing distribution of foramen diameter into intervals



Graph 2: Showing comparison of distribution of value of indexes 11 and 12 in respective histograms

Table 2: Showing distribution of nutrient foramen of humerii

Surfaces	Number of Foramina	Percentage
AMS	64	55.17%
ALS	3	2.58%
	20	17.24%
MB	27	23.27%
AB	2	1.72%
LB	0	0.00%

4. Discussion

The aim of this study was to study the precise Anatomy of the nutrient foramina in adult human humerii of Indian subjects. The healing of fracture depends on various factors like severity of the injury, poor blood supply, age, nutritional status of patient.[3] The nutrient artery is the source of blood to the medullary cavity and inner two-thirds of the cortex of the humerus. It enters through nutrient foramen and the canal.[8]

Laing studied the vascularity of the humerus he stressed that the main artery of the humerus must be protected from injuries during operations which are done on the humeral shaft.[9] The knowledge of variation of nutrient foramina is significantly important for orthopedic surgeons undertaking

Table 3: Showing distribution of nutrient foramen in respect to zone of humerii

Zones on the bones	The Number of foramina	Percentage	The Number of dominant foramina	Percentage
Zone 1	8	6.89%	4	4.87%
Zone 2	103	88.79%	75	91.46%
Zone 3	5	4.31%	3	3.65%

Table 4: Distribution of number of foramina in histograms of distance from the mid- point

Intervals	All Foramina	Dominant Foramina
0-10	8	1
10-20	25	22
20-30	29	23
30-40	27	21
40-50	20	11
50-60	3	22
60-70	3	22
70-80	1	0
80-90	0	0
90-100	0	0

an open reduction of fracture to avoid injuring the nutrient artery and thus lessening the chances of delayed or non-union of the fracture.[10] The lack of arterial supply causes the delayed union or non-union of fracture.[11]

The present study showed that single nutrient foramen was present in 60.40% of humerii. Rita and Renu[1] studied 64 bones of which 90.62% had a single foramen which is more for the values observed in this study. In Xue Z[2] study, of the 38 bones 84.21% had a single foramen. InShanta and Shanta[3] study of the 258 bones 76.74% had a single foramen, this incidence is still higher from this study. However Mansur and Manadhar[4] reported that 60.87% of the humerii had a single foramen. Similar findings were reported by Shaheen[12] that is 60%. Almost similar trend also reported by Mysorekar et al. (58%) in Indian population and Joshi et al.(63%) among Gujarati population.[5,10] A study done from University Western Ontario by Carrol et al.observed that 67.61% of the 71 humerihad single nutrient foramen.[7]

The present study showed that the prevalence of double nutrient foramina were found to be 29.06%·Carrol[7] and Mansur[4] reported 28.16% and 28.85% respectively.[4,7] Shanta C[3] reported 20.54%.[3] In contrast to these, few authors like Rita[1] and Xue[2] reported 7.8% and 13.16% respectively.[1,2] Only few authors had observed the presence of triple nutrient foramina in the humeri. Similarly, the present study observed 5.81%, Shaheen[12] reports 6.7% and Mansur[4] reported 6.32%. He also reported presence of quadruple nutrient in 5 humeri that is 1.98%.

In the present study, it has been observed that a few humerus had no foramina at all. Of the 86 bones observed in this study 4.56% had no foramen. Xue[2] had 2.63%, Rita[1] had 1.56% and Mansur[3] reported 1.98% had no foramen in the humerus. However, most of the authors in their studies have agreed that majority of the humeri had a single artery at a higher incidence compared to that of having multiple nutrient foramina or none.

The location of the nutrient foramina varies in position. The results of this aspect of the present study cannot be compared effectively to other papers and studies as the position of possible location of the nutrient foramina on the surfaces of the humerus bone was kept 6. The surfaces were Anterio Medial Surface (AMS), Anterio Lateral Surface (ALS), Posterior Surface (PS), Medial Border (MB), Lateral Border (LB), and Anterior Border (AB) in this study. Others considered only 3locations. Thus the results reported here is a novel data. The present study shows that most of the nutrient foramina were present in the anteromedial surface (55.17%) of the 116 nutrient foramina that were noted. 17.24% of which were found on the posterior surface, only 2.58% were found on the anterolateral surface. 23.24% the nutrient foramina were situated on the medial border and 1.72% on the anterior border and none on the lateral border.

The present study does follow the set parameters of possible location of the nutrient foramina based on the 3 equally divided Zones of the length of humerus·Majority of nutrient foramina is found in Zone 2 (middle 1/3rd) that is about 91.46%. Zone 1 and Zone 3 has 4.87% and 3.65% of the nutrient foramina respectively which was in close comparison to Mansur's study[4] where 94.84% of the foramina were found in Zone 2, whereas Shanta C[3] and Rita K[1] found about 86.43% and 81.25%respectively on the middle 1/3rd or Zone 2.

Studies have been conducted to observe the direction of the nutrient foramina in humerii to determine that whether it follows the law of ossification or not. Berard reported that the direction of the nutrient Foramina of humeri was constant and the nutrient canal slanted towards that end at which the epiphysis was first united with the shaft of humerus.[13] The direction of the nutrient foramina were directed horizontally before birth but as the growth proceeds the direction of nutrient foramina were directed from the growing end of the humeri. The present study recorded that the direction of all the nutrient foramina of the humeri was directed towards the distal end the humeri which is supported by many studies.[2,14–16] Kumar et al. did report that they found one nutrient foramen that was directed towards the proximal end/upper end.16 Hughes also noted that anomalous foramina were extremely rare in the human humerus but were common in other species.[17] Therefore, the present study concludes that all nutrient foramina present in the humeri was directed distally which indicates that it follows the law of ossification.

The size of the nutrient foramina hasn't been widely discussed. The present study found the mean foramen diameter was found to be 0.814±0.213 mm (range 0.33-1.48mm) which is accordance to Shanta C[3] (0.828±0.26 mm). Xue Z[2] reported a higher value of 1.12±0.32 mm.

The foramina index was introduced by Hughes to give an understanding of the most probable position of the nutrient foramina.[17] Xue Z identified that this is a theoretical parameter that cannot be applied to clinical practice and introduced the landmark index.[2] The epicondyles are more prominent than the proximal landmarks and the medial epicondyle is on the same side as the nutrient foramina, and therefore they modified the indices by calculating them from the distal end. Andour study followed this and calculated both these indexes to understand the comparison and which would add a message to the existing knowledge. The values obtained differed to a small scale of a max of ±4. This validates both the indexes, although Landmark Index introduced by Xue Z. is more clinically practical. The mean I1 (Foramina Index) was 56.835±7.802% (range 29.71% - 72.64%), while the I2 (Landmark Index) had a mean value of 56.299±7.750% (range 29.51% - 72.03%). Which doesn't consider with the findings of Xue Z. The mean Foramina Index (I) was 43.76±4.94% (range 31.49–53.08%) and the mean landmark index (I) was 42.26±5.35% (range 28.20–52.53%).[2] The possible reasons for the gap in values could be one as Xue Z points out that all of their specimens were Chinese and ours comprising only Indians. These observation may not necessarily be extrapolated to other populations.

Therefore this study wishes to present a non-invasive palpable clinical procedure that enables Surgeons and Orthopedic doctors working to treat on the arm of the upper limb a suggestive pre-operative assessment of knowing the most probable location of the nutrient foramen of the humerus which is the entry point of the nutrient artery, that will give the idea, if the fracture that could have occurred in that area could have possibly insulted the nutrient artery or if any surgery taking place on the arm of the upper limb especially by the shaft of the humerus and therefore treat the fracture with more care and indicate surgeons to treat more carefully in this area as it could damage the nutrient artery, that might lead to a poor prognosis and if left unchecked could lead to delayed union or non-union of the bone after a possible fracture of the patient in the future.

The 'Span-fold' procedure is simple and effective pre-surgical/diagnostic technique and follows as the name suggests. First the clinician uses the thumb of same side of arm they palpating and place the tip of the thumb on the medial epicondyle and spread the palm as wide as possible so the last digit is towards the proximal end of the bone (or the shoulder) and then by keeping the first three digits of the hand to spread out, fold them laterally so that they can hold the arm. The area underneath the point of the proximal interphalangeal joint (PIP joint) of the first folded digit to the point of PIP joint of the third folded digit is the most probable area where the dominant nutrient artery is mostly present, more probability towards the base of the fingers (first 3 digits) which decreases as it reaches the finger tips. The 'Span-fold' procedure was derived from cumulative knowledge observed, recorded and assessed during this study. The distribution of location of the nutrient foramina on the surfaces of the humerus bone where it was found most of the dominant foramina were on the anterior median surfaces and medial border and posterior surface, all of which covered by the 3 digits and very small fraction of it lied on the anterolateral surfaceand none on the lateral border. This method is also based ofthe mean indexes (I1 and I2) that was calculated during this study, I1 was 56.835±7.802% (range 29.71% - 72.64%) while the I2 had a mean value of 56.299±7.750% (range 29.51% - 72.03%). The average hand span is 17.5-21.5 cms. The area between the points of PIP joints of first and third digit as kept in the 'Span-fold' position would give the equivalent to the indexes being in the range of 25% to 65% which is the most probable point of Landmark Index. The foramina were present at this site is 64.63%. The knowledge of anatomy of nutrient foramina is also crucial when surgeries are required in cases where the nutrient artery is not impacted or the dissection of the anteromedial humerus is necessary.[2]

Since we have discussed anatomical structures are located by palpable landmarks in surgeries, the Landmark Index and the 'Span-fold' procedure could efficiently help surgeons to locate the foraminal area and avoid disturbing the nutrient foramina.

Limitations of the present study was, it was a retrospective study. Though the study was conducted on adult humeri, this may not be applicable on children. The exact determination of the sex was not studied. No radiological methods used. The number of specimen studied was of a moderate size. The numerical data was manually calculated and not on a statistical analysis software where error percentage would very less.

5. Conclusion

This study concludes that the nutrient foramina of the humeri were not only located on the anteromedial surfaces but also on the medial border and the posterior surfaces. Similarly, the nutrient foramen of the humerus was found on both the middle and the lower third of the shaft. A majority of the humeri had a single nutrient foramen, though some humeri had more than one nutrient foramen. Both the Foramina Index and the Landmark Index can help clinicians locate the nutrient artery. The 'Span-fold' procedure would make this index useable in the practical field. Fractures passing through the foraminal area may lead to poor prognosis. The dissection of this region should be avoided in surgeries and if necessary, it should be done with extra care and the accessory arteries should be protected when the main nutrient artery is disturbed. The location of nutrient foramina is also essential in reconstructive and plastic surgery.

6. Source of Funding

None.

7. Conflict of Interest

The authors declare no conflict of interest.

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Cite this article: Arfan N K, Suresh N M, Suma M P. A morphometric study on variations of nutrient foramen of humerus with its clinical implication. *Indian J Clin Anat Physiol* 2022;9(1):29-34.