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Anatomy Section

Topographical Variations of Nutrient Foramina in the Dry Adult Scapula: A Cross-sectional Study

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ABSTRACT

Introduction: The scapula is the shoulder girdle bone. Vascularity of this bone may arise from the subscapular and circumflex scapular arteries (on the lateral border), supra-scapular artery (on the superior border), deep branch of the transverse cervical artery (on the medial border), or a branch from the axillary artery (on the costal surface). Nutrient arteries associated with flat bones like the scapula have not received significant research in the past.

Aim: To determine the number and location of nutrient foramina on the human dry scapula.

Materials and Methods: This descriptive cross-sectional study was conducted in the Department of Anatomy of RG KAR Medical College, Kolkata, West Bengal, India.. The sample was gathered from August 2022 to January 2023. A total of 122 dry adult scapulae were studied (69 right and 53 left), irrespective of age and sex. The data obtained after thorough inspection was tabulated to obtain the results. The International Business Management(IBM) Statistical Package for Social Sciences(SPSS) software tool was used for statistical analysis, and inferences were drawn from the results.

Results: The average number of nutrient foramina per scapula was five (ranging from 2 to 10). The most common location of the supraspinous fossa was 30.97%. On the costal surface, most of the nutrient foramina were found directly inferior to the suprascapular notch (30%), and on the dorsal surface, nutrient foramina were identified under the spine of the scapula (23.75%). Nutrient foramina were least present in the peri-glenoid area (15.28%). The Analysis of Variance(ANOVA) test showed homologous subsets between and within the different types of fossae.

Conclusion: To maintain the health of the scapula, the nutrient artery must be preserved. Most scapulae had more than one nutrient foramina, located in specific areas on both the dorsal and costal surfaces of the shoulder blade. As a result, orthopaedic surgeons performing scapular surgery place great significance on their topographic understanding of the nutrient foramina. A knowledge of these variations aids surgeons in minimising blood loss during surgical implications around the pectoral girdle or scapular area in living patients.

Keywords: Pectoral girdle, Scapula, Surgical implications, Vascularity

INTRODUCTION

The scapula, also known as the shoulder blade, is one of the important structures of the pectoral girdle. This flat-shaped scapula is situated along the posterior aspect of the chest wall. The scapula is composed of two thin layers of compact bone enclosing the red bone marrow containing the cancellous bone near the glenoid cavity [1]. Usually, during the embryonic life, all the bones adapt to their mechanical environment along with naturally occurring holes or nutrient foramina for the passage of nutrient vessels through the bone cortex. The scapula is no exception in this matter [2]. The arterial supply of the shoulder blade comes through several vessels that enter the bone at different levels [3]. However, the position of the nutrient foramen and the direction of the nutrient canal are almost constant and characteristically directed away from the growing end of the bone [4]. Nutrient foramina in the scapula usually lie near the suprascapular fossa of the dorsal surface and transmit the nutrient artery from branches of the axillary artery or subclavian artery. This artery can be damaged by fracture or due to surgical exposure related to the shoulder joint, which can lead to excessive blood loss during surgery and nonunion of bone fragments [5].

Scapular foramina have been reported by several researchers in earlier studies. Singh N et al. reported 7.5% (9 out of 120) of scapulae in the North Indian population, Yurasakpong L et al. reported 78% (117 out of 150) of scapulae in the Thai population, and Donders JCE et al. observed a mean of 5 nutrient foramina (ranging from 2 to 10) [6-8]. The majority of them were noted in the supraspinous fossa (29.7%), and very few were located in the peri-glenoid area of the scapula. Knowledge of the position of the nutrient artery on the bone is important for the successful outcome of external or internal fixation with nails, screws, plates, and surgical bone grafting [9], which is essential for proper fracture healing [10]. Without this knowledge, any vascular complication may occur even after surgical repair of a fracture. Nutrient foramina of the scapula in this region were the subject of scant information. Therefore, this study was conducted to determine the numbers and positions of the nutrient foramina and the direction of the nutrient canal, which can be helpful in formulating orthopaedic and microvascular surgical procedures more appropriately.

MATERIALS AND METHODS

This was a cross-sectional descriptive study conducted from August 2022 to January 2023. The study was conducted in the dry anatomy museum of RG KAR Medical College, Kolkata, West Bengal, India.. A total of 122 dry unpaired cleaned adult human scapulae were included in the study, with 69 on the right side and 53 on the left side. These scapulae were randomly collected from the region in and around Kolkata, West Bengal, over several years. The specific age and sex of the scapulae were not known, and damaged and deformed bones were excluded from the study.

Procedure

The bones were thoroughly examined to determine the number and location of foramina with respect to the surface. Nutrient foramina were identified by the presence of a well-marked groove with a slightly raised margin at the beginning of the canal. The direction of the canal was determined using a 24G needle (0.51 mm). The entry point of the nutrient foramina was slightly raised on the bony surface, and the 24G needle was introduced through them. Nutrient foramina with a diameter of 0.51 mm or larger were included as a parameter in this study, following the standard method used in previously published articles [8].

STATISTICAL ANALYSIS

All continuous data were expressed as a mean and standard deviation. IBM_SPSS was used for statistical analysis, with a 5% confidence interval. ANOVA test was used to compare between and within the different types of fossae.

RESULTS

A total of 720 nutrient foramina were found in 122 scapulae in various fossae (Subscapular fossa, supra-spinous fossa, and infraspinous fossa), as well as around the lateral angle of the scapula. On average, each scapula had three nutrient foramina, ranging from 2 to 10. Most scapulae (98.36%) had more than two nutrient foramina, while the remaining 1.64% had only two nutrient foramina. The positions of the nutrient foramina were categorised according to the topographic area [Table/Fig-1].

Topographic area	No. of NF (n=720)	No. of scapulae (n=122)	Mean±SD (Range)
Supra-spinous fossa	223 (30.97%)	122 (100%)	1.8±0.76
Infra-spinous fossa	171 (23.75%)	108 (88.52%)	1.4±0.8
Subscapular fossa	216 (30%)	118 (96.72%)	1.8±0.8
Near lateral angle			
a. Anteriorly	88 (12.12%)	70 (57.38%)	0.8±0.7
b. Posteriorly	10 (1.27%)	3 (2.46%)	
c. On both side	12 (1.66%)	6 (4.92%)	
d. Absent		On 43 scapulae (5.97%)	
Total NF	720	122	5.90±0.9
Extra foramina	5 in right	8 in left	0.1±0.3

[Table/Fig-1]: Number of nutrient foramina per topographical area.

followed by the infraspinous fossa (23.75%) and near the lateral angle. Nutrient foramina near the lateral angle or glenoid were observed to be distributed as follows: the majority of the foramina were seen on the anterior aspect of the glenoid (12.12%), followed by the posterior aspect (1.27%). In 1.66% of scapulae, the nutrient foramen was present on both sides of the lateral angle.

This study observed that no scapula lacked nutrient foramina. Even if there was only a single nutrient foramen, it was located in the supraspinous fossa. The supraspinous fossa of the scapula contained at least one nutrient foramen in each scapula [Table/Fig-5].

On the costal surface, most of the nutrient foramina were found near the superior border of the bone, approximately 2-3 cm below it. Nutrient foramina were mostly found on the anterior surface, between the coracoid process and surgical neck of the scapula. There were 55 nutrient foramina near the axillary border of the scapula on the costal surface. On the dorsal surface of these specimens, nutrient foramina were found more in the supraspinous fossa (30.97%) than in the infraspinous fossa (23.75%) [Table/Fig-6-10]. The majority of the nutrient foramina on the supraspinous fossa were found at the spino-glenoid notch, with only a few located in the middle of the supraspinous fossa over the upper surface of the crest of the scapular spine. In 13 scapulae, the suprascapular notch converted into a foramen, but those foramina did not lead to any nutrient canal on the bony surface. So, they were considered as extra-foramina but not nutrient foramina [Table/Fig-11].

				95%Confidence Interval			
				Mean			
	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Supra-spinous fossa	1.8279	0.75725	0.06856	1.6921	1.9636	1.00	4.00
Infraspinous fossa	1.4098	0.82074	0.07431	1.2627	1.5569	0.00	4.00
Subscapular fossa	1.7705	0.81095	0.07342	1.6251	1.9158	0.00	4.00
Lateral angle	0.8115	0.73104	0.06618	.6804	0.9425	0.00	4.00
Extra foramen	0.1066	0.30982	0.02805	.0510	0.1621	0.00	4.00
Total	1.1852	0.96240	0.03897	1.1087	1.2618	0.00	4.00

[Table/Fig-2]: Comparison of the mean and standard (Std.) deviation of the nutrient foramina of scapula of the present study.

In this study, after performing the statistical analysis, the results showed the true mean of scapular nutrient foramina in different topographical areas, with a 95% confidence interval level and upper and lower limits [Table/Fig-2].

The ANOVA test showed a significant difference in the number of nutrient foramina of the scapula between the groups. The p-value was <0.001, rejecting the null hypothesis that all scapulae contain more than one foramen on their surfaces. However, the mean values and differences between the scapular fossae were evident [Table/Fig-2,3].

To identify the significant number of nutrient foramina in different groups of scapular fossae, the Scheffé test was performed [Table/Fig-4].

The maximum number of nutrient foramina was found in the supraspinous fossa (30.97%) and subscapular fossa (30%),

	Sum of Squares	Df (Degree of Freedom)	Mean Square	F Statistics	Significance
Between groups	257.321	4	64.330	126.880	**<0.001**
Within groups	306.746	605			
Total	564.067	609			

[Table/Fig-3]: ANOVA VAR00008 homogenous subsets.

	Homogenous Subsets alpha=0.05			
VAR00007				
Extra Foramen	0.1066			
Near lateral angle		0.8115		
Infraspinous fossa			1.4098	
Subscapular fossa				1.7705
Supraspinous fossa				1.8279
Significance	1.000	1.000	1.000	0.983

[Table/Fig-4]: Descriptive statistics.
Scheffe[a] Test

Number of nutrient foramina	Supraspinous Fossa	Infraspinous fossa	Subscapular fossa	Near glenoid cavity	Extra foramen
0	0%	12.3%	3.3%	35.2%	89.3%
1	35.24%	42.6%	35.2%	50.8%	10.7%
2	50%	37.7%	44.3%	11.5%	0
3	11.48%	6.6%	15.6%	2.5%	0
4	3.28%	0.8%	1.6%	0	0

[Table/Fig-5]: Percentages of numbers of nutrient foramina in different topographical area.

Nutrient Foramina	Classification	Topographical area	Percentage
Usual type	Type-I	Supraspinous	30.97%
Anomalous	Type-II	Subscapular	30%
	Type-III	Infraspinous	23.75%
Accessory	Type-IV	Near lateral angle	110 (15.28%)

[Table/Fig-6]: Classification of nutrient foramina based upon the percentage.

[Table/Fig-7]: Double nutrient in supra-spinous fossae, Type I.


[Table/Fig-8]: Double nutrient foramina in subscapular fossae, Type-II.
[Table/Fig-9]: Double nutrient foramina in infraspinous fossae, Type-III.
(Images from left to right)


[Table/Fig-10]: Nutrient foramina lateral angle, Type-IV.
[Table/Fig-11]: Extra foramina with double nutrient at the nutrient foramina in supraspinous fossae. (Images from left to right)

DISCUSSION

The majority of researchers [11,12] have reported that the nutrient artery for long bones originates from a single artery, which enters the long bone usually through a single nutrient foramen. However, the study of the nutrient artery related to flat bones like the scapula has not been extensively studied previously [7,8]. The scapula has a rich vascular anastomosis surrounding it. The nutrient artery for the scapula originates from more than one artery, which is the reason for the presence of more than one nutrient foramen on different surfaces of the bone [6].

Donders JCE et al. were the first to report the positions of the nutrient foramina of scapulae in the Netherlands population in 2020 [8]. Similarly, in 2023, Yurasakpong L et al. found topographical variations within and between groups of scapular fossae in the North-eastern Thai population, as was also evident in the present study [7]. In this study, scapular foramina were observed in all topographic areas (supra-spinous fossa 30.97%, subscapular fossa 30%, infraspinous fossa 23.75%, and near the lateral angle 15.28%), although they were predominantly found in the supra-spinous fossa. This is similar to the findings of Donders JCE et al. in the Netherlands population, where nutrient foramina were more common in the supraspinous fossa. Yurasakpong L et al. in the Thai population and the present study in the eastern Indian population showed comparable results, with nutrient foramina being more common in the supraspinous fossa. These variations could be explained by the fact that different ethnic groups have distinct ways of living [Table/Fig-12]. Various small holes were encountered on different surfaces of the scapulae, which were for the attachments of muscles, ligaments, or small vessels. Previously, no literature has suggested the diameter of the nutrient vessel that enters the nutrient foramen, which is why the diameter of the nutrient foramina on the bone has not been extensively studied.

In this study, scapular nutrient foramina were classified into three categories of the four types based on their percentage [Table/Fig-6]. Similarly, Yurasakpong L et al. also classified scapular nutrient foramina based on the direction of the canal with a single opening [7].

Topographical area	Present study No. of NF=720 in 122 scapulae	Donders JCE et al., [8] 2020 No. of NF=158 in 30 scapulae	Yurasakpong L et al., [7] 2023 No. of NF=117 in 150 scapulae
Supraspinous	223 (30.97%)	47 (29.7%)	42 (36.7%)
Subscapular	216 (30%)	41 (25.9%)	36 (31.3%)
Infraspinous	171 (23.75%)	42 (26.6%)	27 (22.8%)
Near lateral angle	110 (15.28%)	28 (17.7%)	12 (10%)

[Table/Fig-12]: Comparison of data between present and previous studies.

The vascularity of the scapula is important for the formation of callus at the site of fracture [13]. Therefore, knowledge of the location and number of nutrient foramina on the scapula is crucial for the successful healing of fractures and operative procedures. Preservation of the nutrient vessels is essential for optimal healing after internal and external fixation or surgical bone grafting. Failure to do so can result in neurovascular issues even after a successful surgery [14-16]. In this study, a diameter of ≥0.51 mm was considered significant for vascular foramina. Most of the vascular foramina were found in the supraspinous fossa, followed by the subscapular fossa, and comparatively fewer were found in the infraspinous fossa [17,18]. There was no evidence of nutrient foramen absence on the surface of the bone [Table/Fig-10]. However, in 2% of scapulae, two nutrient foramina were present. In one specimen, there was an absence of nutrient foramina in the subcostal fossa but the presence of two nutrient foramina, one in the supraspinous fossa and the other in the infraspinous fossa. In another specimen, two nutrient foramina were present, one in the subcostal fossa and the other in the supraspinous fossa. In those cases, it is likely that the bone was vascularised by superficial periosteal arteries and other small vessels only.

Satoni Y et al. conducted a study on pedicle grafting of the scapular graft based on the vascular supply of the scapula, which was based on plastic surgery literature [19]. Wijdicks CA et al. studied the blood vessels around the scapula to identify the relation of the circumflex scapular artery with the suprascapular artery, but they did not mention the penetration on the bony surface, the number of nutrient foramina, and their locations [20]. Similarly, Singh N et al. found that the incidence of scapular foramina was 7.5% (right side >left side), while scapular tunnels were noted in 15.8% of cases (left side >right side), and these tunnels were sinuous (50%), curved (39%), or straight (10.7%) based on plain and contrast radiographic findings [6].

In this study, the maximum number of nutrient foramina was found in the supraspinous fossa, followed by the subscapular fossa and then the infraspinous fossa. Based on the presence of nutrient foramina in different topographical areas, the present study classified them into four categories. This research also found accessory nutrient foramina in a significant percentage around the lateral angle of the scapula. These findings were established by ANOVA and Scheffé tests [Table/Fig-8,9]. The data acquired from this study were compared with previous studies [7,8], and most of the findings were similar, except for the presence of accessory nutrient foramina, which were less in the present study.

Scapular fractures most commonly occur at the surgical neck of the scapula, which is near the lateral angle of the bone [19]. Nowadays, various orthopaedic surgeries, such as shoulder joint replacement, are performed for various reasons. Therefore, orthopaedic surgeons should be aware of the rich vascular supply of that region, which includes different nutrient arteries arising from major vessels and entering through various nutrient foramina on the surfaces of the scapula. This information may be helpful during operative procedures to minimise the blood loss and secure the nutrient artery, leading to improved healing of fractures or improved management of conditions affecting the bone.

Limitation(s)

The data represented in the present study emphasise the need for larger sample sizes and multicentre studies, which would provide more accurate results. If the age and sex of each individual bone under study were known, it would be possible to achieve results tailored to a particular age and gender. Additionally, the results were not correlated radiologically.

CONCLUSION(S)

The current study demonstrates significant topographical variations in the scapular nutrient foramina, including the presence of accessory nutrient foramina. These findings can be valuable for orthopaedic surgeons when evaluating surgical procedures, as they should be aware of the topographic distribution of nutrient foramina on the scapula in order to minimise the risk of vascular injury.

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REFERENCES

[1] Standring S, Healy JC, Jhonson D, Collins P, et al. editors. Gray's Anatomy the Anatomical Basis of Clinical Practice. 41st ed. London: Elsevier Churchill Livingstone; 2016. P.89-90,1403-5p.
[2] Gotzen N, Cross AR, Ifju PG, Rapoff AJ. Understanding stress concentration about a nutrient foramen. J. Biomech. 2003;36(10):1511-21.
[3] Moni AS. Medical Anatomy (Regional & Applied) Vol.I Extremities. 3rd ed. Tirnulveli: U. Bhugathy Publisher:2009,10.
[4] Xue Z, Ding H, XU H, An Z. An anatomical study of the nutrient foramina of the human humeral diaphysis. Med Sci Monit. 2016;22:1637-45. Avalable at: http://doi.or/10.12659/msm.898361.
[5] Moore KL, Dalley AF, Agur AMR. Moore clinically Oriented Anatomy. 7th ed. Philadelphia: Lippincott Williams and Wilkins. 2014,527.
[6] Singh N, Chauhan P, Loh HK, Kohli M, Suri RK. Enigma of Scapular foramen and tunnels: An untold story. Surg Radiol Anat. 2018;40:327-32. Avalable at: http://doi.org/10.1007/s00276-017-1931-y.
[7] Yurasakpong L, Suwannakhan A, Kirisattayakul W, Samrid R, Iamsaard S, Limwachiranon J, et al. Topographical study of scapular foramina and scapular nutrient foramina in dried skeletons. Surg Radiol Anat. 2023;45(5):563-70. Avalable at: http://doi.org/10.1007/s00276-023-03132-9.
[8] Donders JCE, Prins J, Kolen P, Streekstra GJ, Cole PA, Kleipool RP, Dobbe JGG. Three-dimensional topography of scapular nutrient foramina. Surgical and Radiological Anatomy. 2020;42(8):887-92. Avalable at: http://doi.org/10.1007/s00276-020-02441-7.
[9] Huang HK, Chiang CC, Hung SH, Su Yp, Chiu FY, Liu CL, et al. The role of autologous bone grft in surgical treatment of hypertrophic non-union of midshaft clavicle fracture. J Chin Med Assoc. 2012;75(5):216-20.
[10] Ambekar SA, Surke SB. Diaphyseal nutrient foramen of lower long bones: Variations and importance. Int J Anat Res. 2016;4(3):2684-88. Avalable at: http://doi.org/10.16965/ijar.2016.306.
[11] Chavada HS, Jethva NK. Morphometric study of nutrient foramen of adult human tibia bone. IJARS. 2019;8(2):AO05-08.
[12] Ghosh T, Ray MK. Anthropometric analysis of nutrient foramen of tibia-A study in eastern India. Int J Res Rev. 2020;7(2):100-03.
[13] Filipowska J, Tomaszewski KA, Niedzwiedzki L, Walocha JA, Niedzwiedzki T. The role of vasculature in bone development, regeneration and proper systemic functioning. Angiogenesis. 2017;20(3):291-302. PMID:28194536 http://doi.org/10.1007/s10456-017-9541-1.
[14] Longia GS, Ajmani ML, Saxsena SK, Thomas RJ. Study of diaphyseal nutrient foramina in human long bones. Act Anat. 1980;107(4):399-406.
[15] Gumusburun E, Yucel F, Ozkan Y, Akgun Z. A study of nutrient foramina of lower limb long bones. Surg Radiol Anat. 1994;16(4):409-12.
[16] Aggarwal P, Ghorai S. Variations in nutrient foramina of clavicle-A descriptive study. National Journal of Clinical Anatomy. 2021;10(3):160-63.
[17] Sendemir E, Cimen A. Nutrient foramina in the shafts of lower limb long bones: Situation and number. Surg Radiol Anat. 1991;13(2):105-08. Avalable at: http://doi.org/10.1007/BF01623881.
[18] Murlimanju BV, Prashant KU, Prabhu LV, Kumar CG, Pai MM, Dhananjay KV. Morphological and topographical anatomy of nutrient foramina in lower limb bones and its clinical importance. Australs Med J. 2011;4(10):530-37. Avalable at: http://doi.org/10.4066/AMJ.2011.725.
[19] Santoni Y, Shimuizu H, Beppu M. Clinical anatomical study of pedicled vascularised scapular bone graft using the angular branch. Hand Surg. 2007;12(1):19-28. Avalable at: http://doi.org/10.1142/S0218810407003407.
[20] Wijdicks CA, Armitage BM, Anavian J. Vulnerable neurovascular with a posterior approach to the scapula. Clin Orthop Relat Res. 2009;467(8):2011-17. Avalable at: http://doi.org/10.1007/s11999-008-0635-3.

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