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ORIGINAL ARTICLE

Vascular foramina of talus: an anatomical study with reference to surgical dissection

P. C. Vani[1] · G. Arthi[1] · J. P. Jessy[1] · Neerja Rani[1] · Saroj Kaler Jhajhria[1]

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Abstract

Purpose To study the distribution and morphometry of vascular foramina of adult human talus in Indian population.
Methods The study was carried out by using 56 adult human tali. The location, size, number and foraminal index of vascular foramina on head, neck and body of each bone were examined macroscopically. The difference in location of vascular foramina was further studied in relation to the pattern of calcaneal articular facets on talus.
Results The vascular foramina were present on the superior neck, inferior neck and medial surface of talar body in all (100%) the bones. The Kruskal–Wallis test followed by series of Mann–Whitney test for post hoc analysis showed the number of vascular foramina was significantly greater on inferior surface of neck and medial surface of body. The number of vascular foramina ranged from 0 to 25. About 77.05% of foramina were $\geq$ 0.5 mm in size. The mean foraminal index of the closest foramina on inferior surface of neck and medial surface of body was 47.90% and 37.23%, respectively. The mean foraminal index of the farthest foramina on inferior surface of neck and medial surface of body was 75.08% and 71.35%, respectively.
Conclusion The present study has provided additional information on the vascular foramina of tali. This knowledge is important to the orthopedic, vascular and podiatric surgeons while performing the surgeries of hind foot. We opine that the lateral approach would be more beneficial in the surgical procedures to talus.

Keywords Talus · Fractures · Morphometry · Osteonecrosis · Vascular foramina

Introduction

The talus which forms the keystone of medial longitudinal arch also acts as an osseous link between the foot and leg [2]. It consists of a neck and head projecting forward and slightly medially from the cuboidal body [5]. The extraosseous arterial supply entering through vascular foramina on the bony surface is from the branches of posterior tibial, dorsalis pedis and fibular arteries [2]. These vascular foramina give passage to the blood vessels of the medullary cavity [10].

The knowledge of the vascular foramina may help in understanding the vascularity of different surfaces of talus. The topography of the arterial supply may also help in the assessment of the risk of vascular damage involved in surgical approaches of talus. The present study was conceptualized keeping the fact that there are no studies reported in the literature to the best of our knowledge about the vascular foramina of the talus in Indian population. The aim of the present study is to provide reference data on the distribution and morphometry of talar vascular foramina in Indian population.

Materials and methods

The study was conducted on 56 dried human tali obtained from the Department of Anatomy, All India Institute of Medical Sciences, New Delhi, India. Bones with distorted gross features and damage were excluded from the study. Age and gender of the bones were not known. The side determination of the bones was done using various anatomical features [2]. The tali were also divided into three types based on calcaneal facets: type A with separate anterior, middle and posterior facet, type B with fused anterior, middle facets and separate posterior facet and type C with fused anterior, middle and posterior facets [4].

✉ Saroj Kaler Jhajhria
sarojkaler@gmail.com

1 Department of Anatomy, All India Institute of Medical Sciences, First floor, Teaching Block, New Delhi 110029, India

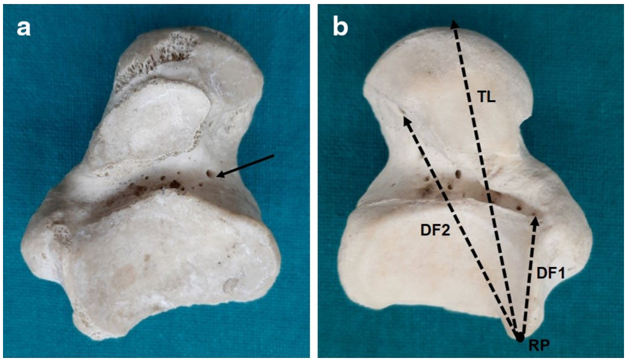

Fig. 1 Representative photographs showing **a** left talus with well-marked groove leading to vascular foramen (down arrow) on inferior surface of neck. **b** Right talus with the measurements on inferior surface of neck. *RP* reference point—midpoint of posterolateral tubercle, *DF1* the distance from the RP to closest vascular foramina, *DF2* the distance from the RP to farthest vascular foramina, *TL* total length of the talus)

The vascular foramina were identified by the presence of a well-marked groove leading to foramen and canal representing the site of entry of the vessel (Fig. 1a). The patency of the foramen was confirmed by passage of Krischner wire (K wire) with a diameter of 0.5 mm. The head, neck and body of the tali were macroscopically examined for the foramina on both articulating and non-articulating surfaces using a magnifying hand lens. The other parameters studied were the location, number and size of the vascular foramina on various surfaces of the different parts of tali. Those foramina which did not allow the k wire to pass through were classified as < 0.5 mm in size, and those which allowed the k wire to pass through were classified as ≥ 0.5 mm in size.

The most posterior point on posterolateral tubercle of the talus was taken as the reference point (RP). The closest and farthest foramina from the RP were identified on the inferior surface of neck and medial surface of the body of each talus. The following measurements were made (Fig. 1b).

1. *TL* Total length of talus measured as the distance from the RP to most anterior point on the head of the talus.
2. *DF1* The distance measured from the RP to the closest foramina on the inferior surface of talar neck.
3. *DF2* The distance measured from the RP to the farthest foramina on the inferior surface of talar neck.
4. *DF3* The distance measured from the RP to the closest foramina on the medial surface of talar body.
5. *DF4* The distance measured from the RP to the farthest foramina on the medial surface of talar body.

The foraminal index was calculated using the formula DNF/TL × 100, where DNF is the distance of the foramina measured from the RP and TL is the total length of the tali. FI1 and FI2 represented the foraminal index of the closest and farthest foramina, respectively, on inferior surface of the talar neck. FI3 and FI4 represented the foraminal index of the closest and farthest foramina, respectively, on medial surface of the talar body. The measurements were made using the digital Vernier caliper with accuracy of 0.02 mm (Aerospace). The counting and measurements were done by the same person twice to avoid the inter-observer error. Statistical analysis was done using the SPSS version 13.0 (SPSS Inc., Chicago, IL, USA). The Kruskal–Wallis test was used to compare the number of foramina on various surfaces of the bone followed by series of Mann–Whitney *U* test for the post hoc analysis. The Kruskal–Wallis test was also used to compare the types of the talus with the number of foramina on each surface of the tali. The Mann–Whitney *U* test and Student's unpaired "*t*" test were applied to find statistical difference between right- and left-sided bones. A p value < 0.05 was taken statistically significant.

Results

In all the tali (100%), vascular foramina were observed over the non-articular surfaces. The foramina were absent on head of the tali but were present on various surfaces of neck and body of the tali.

The talar neck presented foramina on superior, inferior, medial and lateral surfaces (Fig. 2). The inferior and medial surfaces of the neck presented the maximum and the least number of foramina, respectively. The complete absence of foramina on the lateral and medial surfaces of talar neck was

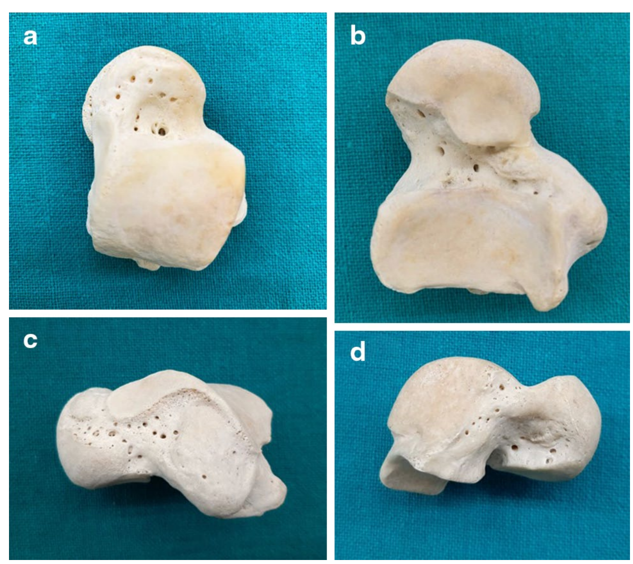

Fig. 2 Representative photographs showing different surfaces of right talus with vascular foramina on **a** superior surface of neck. **b** Inferior surface of neck. **c** Medial surface of neck and body. **d** Lateral surface of neck and body

seen in 19.64% and 5.36%, respectively. The Kruskal–Wallis test showed statistically significant difference in the total number of vascular foramina between the different surfaces of talar neck, $\chi^2(3) = 145.502$, $p = 0.001$, with a mean rank foramina number of 134.69 for superior surface, 182.04 for inferior surface, 92.21 for medial surface and 41.05 for lateral surface. The Mann–Whitney *U* test done for post hoc analysis showed the total number of vascular foramina observed on inferior surface was significantly greater than the number observed on the superior ($U = 689.50$, $p = 0.001$), medial ($U = 102.50$, $p = 0.001$) and lateral ($U = 17.50$, $p = 0.001$) surfaces of the talar neck (Table 1).

The talar body presented foramina over the medial, lateral and posterior surfaces (Fig. 2). The superior and inferior surfaces of talar body did not show any vascular foramina. The medial and lateral surfaces of the body presented the maximum and the least number of foramina, respectively. The complete absence of foramina on the lateral and posterior surface of talar body was seen in 26.79% and 30.36%, respectively. The Kruskal–Wallis test showed that there was statistical significant difference in total number of vascular foramina between the different surfaces of talar body, $\chi^2(3) = 91.419$, $p = 0.001$, with a mean rank foramina number of 134.14 for medial surface, 54.66 for lateral surface and 64.70 for posterior surface. The Mann–Whitney *U* test done for post hoc analysis showed the total number of foramina observed on medial surface was significantly greater than the number observed on the lateral ($U = 119.50$, $p = 0.001$) and posterior ($U = 236.50$, $p = 0.001$) surfaces of talar body (Table 1).

The number of vascular foramina ranged from 0 to 25 on talar neck and 0–16 on talar body (Table 1). The number of the foramina on inferior surface of neck ranged from 2 to 25 with an average of 7 foramina. 94.64% of the bones exhibited ≥ 7 and 5.36% of the bones exhibited < 7 vascular foramina on the inferior surface of talar neck. The number of the foramina on medial surface of body ranged from 2 to 16 with an average of 6 foramina. 51.79% of bones presented ≥ 6 and 48.21% bones presented < 6 vascular foramina on medial part of talar body. Table 2 summarizes the distribution of foramina on various surfaces of neck as well as body between the right and left tali.

Table 3 summarizes the distribution of vascular foramina on various surfaces of neck and body of tali with respect to different talar types. Type B talus ($n = 47$) was the most common talar type followed by type A ($n = 7$) and type C ($n = 2$). No significant difference in foramina number was observed on comparison between the type and the number of foramina on various surfaces of the tali.

Table 1 Distribution of vascular foramina on different surfaces of neck and body of tali ($n = 56$)

Surfaces	Number of vascular foramina			
	Minimum	Maximum	Mean	Total (%)
Neck				
Superior	1	14	7	404 (29.77%)*
Inferior	2	25	12	655 (48.27%)
Medial	0	9	3	102 (7.52%)**
Lateral	0	7	1	196 (14.44%)***
Body				
Medial	2	16	6	345 (69.70%)
Lateral	0	7	1	64 (12.93%)#
Posterior	0	7	2	86 (17.37%)##

*Indicates statistically significant difference in the total number of foramina on inferior surface of neck when compared to superior surface by the Mann–Whitney *U* test ($U = 689.5$, $p = 0.001$)

**Indicates statistically significant difference in the total number of foramina on inferior surface of neck when compared to medial surface by the Mann–Whitney *U* test ($U = 102.5$, $p = 0.001$)

***Indicates statistically significant difference in the total number of foramina on inferior surface of neck when compared to lateral surface by the Mann–Whitney *U* test ($U = 17.5$, $p = 0.001$)

#Indicates statistically significant difference in the total number of foramina on medial surface of body when compared to lateral surface by the Mann–Whitney *U* test ($U = 119.5$, $p = 0.001$)

##Indicates statistically significant difference in the total number of foramina on medial surface of body when compared to posterior surface by the Mann–Whitney *U* test ($U = 236.5$, $p = 0.001$)

Table 2 Distribution of vascular foramina on different surfaces of neck and body between right ($n = 20$) and left ($n = 36$) tali

Surfaces	Side	Number of vascular foramina			
		Minimum	Maximum	Mean	*p* value
Neck					
Superior	R	1	14	7	1.000**
	L	1	14	7	
Inferior	R	6	20	12	0.219**
	L	2	25	11	
Medial	R	1	7	4	0.108**
	L	0	9	3	
Lateral	R	0	6	2	0.240**
	L	0	7	2	
Body					
Medial	R	2	16	8	0.036*
	L	2	12	5	
Lateral	R	0	7	1	0.158**
	L	0	4	1	
Posterior	R	0	7	2	0.640**
	L	0	6	2	

R right talus, *L* left talus

*Indicates statistically significant difference in the total number of foramina on medial surface of the body between right and left tali by the Mann–Whitney *U* test ($U = 238.0$, $p = 0.036$)

**Difference between right and left tali was statistically insignificant

Table 3 Distribution of vascular foramina on different surfaces of neck and body between type A (n=7), type B (n=47) and type C (n=2) tali

Surfaces	Type	Number of vascular foramina			
		Minimum	Maximum	Mean	p value
Neck					
Superior	A	2	14	8	
	B	1	14	4	0.276*
	C	7	13	4	
Inferior	A	8	25	7	
	B	2	20	4	0.683*
	C	8	22	10	
Medial	A	3	9	2	
	B	0	8	2	0.066*
	C	3	5	1	
Lateral	A	1	4	1	
	B	0	7	2	0.271*
	C	0	1	1	
Body					
Medial	A	6	10	8	
	B	2	16	4	0.192*
	C	5	7	1	
Lateral	A	0	7	2	
	B	0	4	1	0.623*
	C	0	1	1	
Posterior	A	1	7	3	
	B	0	6	1	0.192*
	C	1	1	0	

*Difference between type of tali and number of foramina was statistically insignificant

Table 4 Distances and foraminal index of vascular foramina measured on inferior surface of neck and medial surface of body between right (n=20) and left (n=36) tali

Measurements	Side	Number of vascular foramina			
		Minimum	Maximum	Mean ± SD	p value
TL (mm)	R	37.95	53.22	47.10 ± 4.38	0.083*
	L	39.00	59.75	49.40 ± 4.81	
Neck—inferior surface					
DF1 (mm)	R	13.43	26.12	20.48 ± 2.71	0.685*
	L	8.81	26.31	20.08 ± 3.80	
DF2 (mm)	R	28.66	44.52	36.31 ± 4.47	0.940*
	L	26.58	50.16	36.21 ± 4.70	
FI1 (%)	R	27.73	53.84	43.76 ± 6.46	0.172*
	L	19.03	55.13	40.87 ± 7.97	
FI2 (%)	R	62.92	97.71	77.33 ± 8.92	0.230*
	L	52.26	99.93	73.84 ± 10.99	
Body—medial surface					
DF3 (mm)	R	10.91	29.21	17.60 ± 5.20	0.610*
	L	11.39	30.97	18.31 ± 4.87	
DF4 (mm)	R	30.87	42.66	34.60 ± 3.28	0.746*
	L	24.73	42.40	34.28 ± 3.78	
FI3 (%)	R	26.11	57.66	77.33 ± 8.92	0.981*
	L	24.29	65.34	37.20 ± 9.90	
FI4 (%)	R	62.58	89.41	73.87 ± 7.91	0.137*
	L	53.72	94.36	69.96 ± 9.96	

R right talus, *L* left talus

*Difference between right and left tali was statistically insignificant

The mean total length of tali was 48.58 ± 4.75 mm (range 37.95–59.75 mm). Table 4 and Fig. 3 summarize the measured foraminal index on the inferior surface of neck and medial surface of body of tali. The mean FI1 was 41.90 ± 7.53%, and the majority 28 (50%) of tali had an index of 40–50%. The mean FI2 was 75.08 ± 10.36%, and the majority 22 (39.29%) of tali had an index of 70–80%. The mean FI3 was 37.23 ± 9.82% (range 24.29–65.34%), and the majority 25 (44.64%) of tali had an index of 30–40%. The mean FI4 was 71.35 ± 9.40%, and the majority 24 (42.86%) of tali had an index of 60–70%. Table 4 summarizes the distances and foraminal index of the vascular foramina measured between right and left tali. No statistically significant difference was observed between the right and left tali.

The total numbers of vascular foramina were 1852. Out of these, the majority of foramina 1427 (77.05%) were ≥ 0.5 mm in size. Also on the neck and body of tali, the majority of foramina 1055 (77.74%) and 372 (75.15%) were ≥ 0.5 mm in size, respectively.

Discussion

The talus is the second largest and the only tarsal bone that has no muscular or tendinous attachments. The distal surface of talar head presents an articular facet for navicle and plantar surface presents facets for calcaneus [2]. The plantar aspect of neck presents the tarsal canal, between the middle and posterior facets of the subtalar joint in medial half and the sinus tarsi in lateral half, which together form a funnel-shaped appearance. [3].The talar body presents trochlear tali, lateral process, posterior process with medial and lateral tubercle [12]. Thus, talus takes part in the formation of ankle, subtalar and talocalcaneonavicular joints. The injuries to talus can interfere with the normal motion at these joints resulting in permanent pain and deformity [6].

With three-fifths of talar surface covered by cartilage, only two-fifth can be perforated by vessels [6].The talar head is supplied by medial tarsal, lateral tarsal and tarsal sinus branch of dorsalis pedis artery [9].The talar neck is supplied by anterior malleolar branch of anterior tibial artery, the medial tarsal, lateral tarsal, the tarsal sinus branches of dorsalis pedis artery and tarsal canal branches of posterior

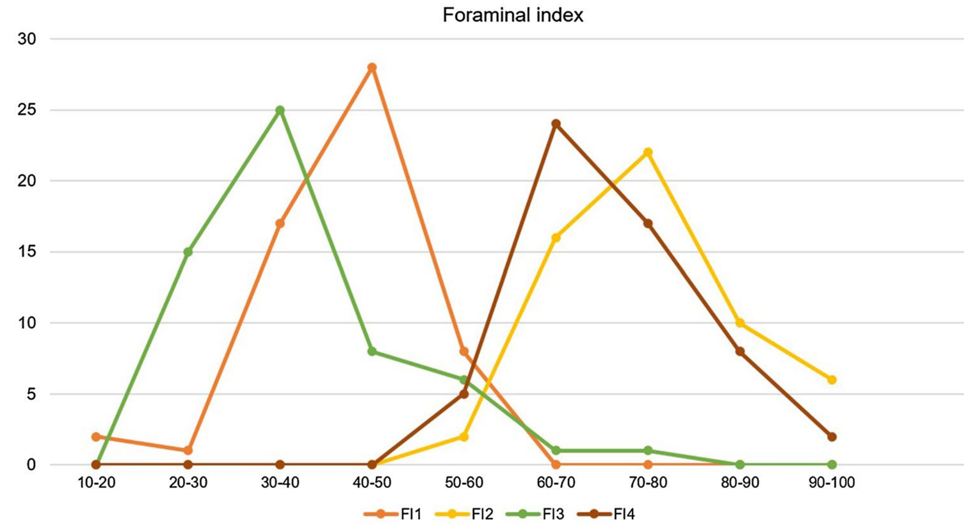

Fig. 3 Line graph showing the foraminal index of the vascular foramina measured on inferior surface of the neck and medial surface of body of the talus

tibial artery [2, 8].The talar body is mainly supplied by deltoid branch of tarsal canal artery [2, 9].

In the present study, the foramina were observed only on the non-articular surfaces of talus similar to that reported in the literature which showed talus is supplied by numerous very small vessels penetrating it through the whole non-articular surface [7]. The previous cadaveric studies have shown the vessels entering the talus through different surfaces such as the superior neck, inferior neck, medial surface of body and posterior process [7, 8]. In the present study, we also observed foramina on the superior neck supplied by branches of dorsalis pedis artery, inferior neck supplied by anastomosis between the tarsal canal artery with the tarsal sinus artery and medial surface of talar body supplied by deltoid branch of tarsal canal artery (Fig. 4). The vessels entering these surfaces being branches of dorsalis pedis and posterior tibial artery form the main source of arterial supply to talus. We also observed that foramina on posterior process were absent in 30.36% of bones, thus differing from the above studies. Our findings also showed the absence of foramina on medial surface of neck in 5.36%, lateral surface of neck in 19.66% and lateral surface of body in 26.79% of bones which has not been reported previously. We observed that the head of talus did not show the presence of any vascular foramina. These findings confirm that the arterial supply to head of talus is provided by the branches entering the neck as described in previous studies [7].The neck presented maximum foramina on the inferior surface similar to other studies in the literature [13].

In the present study, we found type B was more common which is similar to that observed in previous studies [1, 14, 15].The morphology of articular facet of talus and calcaneus is necessary to plan adequate denuding of the articular surfaces of subtalar joints during correctives surgeries involving flat foot or arthritis of subtalar joints [14]. But we did not find any significant difference by comparing the talar type with the distribution of vascular foramina, indicating that the site of vessel entry into the bone is not altered based on the type of calcaneal articular facets on talus.

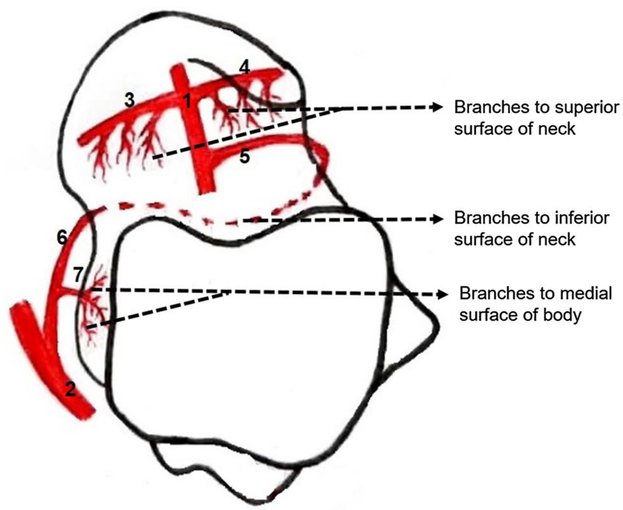

Fig. 4 Schematic diagram showing the arterial supply to right talus—superior view (1—dorsalis pedis artery, 2—posterior tibial artery, 3—medial tarsal artery, 4—lateral tarsal artery, 5—artery of tarsal sinus, 6—artery of tarsal canal, and 7—deltoid artery)

We observed that about 75% of foramina were ≥ 0.5 mm in size. The mean length of talus was 48.58 ± 4.75 mm. This was found to be almost similar to previous studies on Indian population [11, 12, 14]. The information about mean length might help with the designing of instruments used for surgical fixation of talus. The mean foraminal index of the closest foramina on inferior surface of neck and medial surface of body was 47.90% and 37.23%, respectively. The mean foraminal index of the farthest foramina on inferior surface of neck and medial surface of body was 75.08% and 71.35%, respectively. About 75% of foramina observed on neck and body were ≥ 0.5 mm in size. An insight into the distribution of vascular foramina and their foraminal index can help in surgical planning to reduce chances of iatrogenic injuries.

The various surgical approaches used to treat talar neck fractures include anterolateral, anteromedial, posterolateral, lateral, medial malleolar and lateral malleolar osteotomy [9]. In the present study, the presence of foramina as a constant finding on the superior neck, inferior neck and medial surface of talar body shows that the anteromedial or medial approach might cause a considerable damage to the branches of posterior tibial artery, deltoid and tarsal canal artery if not dissected cautiously. The absence of foramina on lateral surface of neck, lateral surface of body and posterior tubercle in 19.66%, 26.79% and 30.36% shows that anterolateral, direct lateral and posterolateral approaches might cause less vascular damage. Hence, a lateral approach is more preferable than a medial approach for talar surgeries. The limitation of the present study includes the gender-related variation was not taken into consideration. We believe the present study has provided a reference data on morphometry of the vascular foramina of tali on Indian population. The findings of present study may become useful for orthopedic, vascular and podiatric surgeons during hind foot surgeries.

Author contributions PCV contributed to data collection, data analysis, and manuscript writing. GA and JPJ performed data collection and manuscript writing. NR and SKJ were involved in manuscript writing/editing..

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standards We state that the present experiment complies with the current laws of the country in which it was performed.

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