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The Importance of the Supratrochlear Foramen of the Humerus in Humans: An Anatomical Study

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Background: The supratrochlear foramen (STF) is an important and relatively common anatomic variation in the lower end of the humerus in humans. Its structure has received increased attention in recent years. Anatomical knowledge of STF is useful for anatomists, anthropologists, orthopedic surgeons, and radiologists. This aperture is of great interest to anthropologists who claim it as one of the points in establishing a relationship between humans and lower animals. The goal of this study was to describe the features of STF of the humerus in the Turkish population.

Material/Methods: All bones were obtained from the Department of Anatomy, Faculty of Medicine and Department of Anthropology, University of Mustafa Kemal, Hatay. A total of 166 dried humeri (83 right side and 83 left side), of which 78 belonged to males and 88 to females, were examined to determine the presence of supratrochlear foramen. Digital vernier calipers were used to measure the maximum width (transverse) and height (vertical) of the STF.

Results: Out of 166 bones, the foramen was present in 18 humeri (4 right side and 14 left side), showing the incidence as 10.8% with unpaired humeri. We observed 4 types of shape: oval, round, triangular, and sieve-like. The average diameter of the long (transverse) axis was 5.93 ± 1.68 mm and the short (vertical) axis was 4.06 ± 0.89 mm. Some of the bones showed translucency of the bony septum, found in 17 (20.5%) on both sides of the humeri.

Conclusions: There are few studies about STF in the Turkish population. Knowledge of supratrochlear foramen in the distal humerus in humans is important in diagnostic orthopedics, in intramedullary nailing of the humerus, and in possibly increasing the risk of future low-energy fractures. In addition, STF is a radiolucent area in radiographs and may be misinterpreted as an osteolytic or cystic lesion.

MeSH Keywords: **Anatomy • Humerus • Observer Variation • Supratrochlear Foramen**

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Background

The supratrochlear foramen (STF) is an important and relatively common anatomic variation in the lower end of the humerus in humans. The supratrochlear foramen (STF) of the humerus has been neglected in standard anatomy and orthopedics books. In recent years it has become clear that STF should be emphasized because anatomical knowledge of STF is useful for anatomists, anthropologists, orthopedic surgeons, and radiologists.

A thin plate of compact bone known as supratrochlear septum, which is lined by a synovial membrane, usually separates the olecranon fossa and coronoid fossa in the supratrochlear area of the distal part of the humerus [1–5]. This bony septum is opaque or translucent and septum in some cases may become perforated to form a foramen called as supratrochlear aperture, septal aperture, intercondylar foramen, or epitrochlear foramen, but is most commonly referred to as supratrochlear foramen (STF) [6–8]. The perforation lies between the lateral and the medial epicondyle [9]. The supratrochlear foramen was first described by Meckel in 1825 [3,10,11]. Although it may have different shapes, STF are mainly oval, round, triangular, sieve-like, and irregular [1,2]. Studies have shown that the humerus is not perforated in the embryonal stage [12]. The septum is present until 7 years of age, after which it is occasionally absorbed to form STF [13,14]. The supratrochlear foramen has, apart from its evolutionary significance, much clinical importance. The significance of the presence of coronoid-olecranon septal perforation was not clinically an atypical fracture pattern of distal humerus in teenaged boys [12,15]. It is of some clinical significance that it may predispose to low-energy fractures of the distal humerus [12]. The septal aperture is located along the narrow medullary humeral canal and extreme anterior angulation at the distal part of the humerus [3,16]. Studies have shown that the distal portion of the medullary canal in humeri with septal aperture was narrower and shorter at the entry point of a retrograde nail than in humeri without a septal aperture. Features of the intramedullary canal are important in the treatment of supracondylar fractures, especially following traumatic injuries and pathologic fractures and also in intramedullary nailing procedures [11,13,17–19]. Nayak et al. observed in plain radiographs that the SA was located closer to the medial epicondyle, resulting in difficult intramedullary nailing [14]. In the literature, the supratrochlear foramen of the humerus has been defined as co-existent with the supracondylar process in the same humerus [20]. Additionally, the SA is a relatively radiolucent area, commonly described as a “pseudo lesion” in an x-ray of the upper limb and can be mistaken as an osteolytic or cystic lesion [14,21,22]. The osteochondritis dissecans of the septum supratrochlear is the result of an incomplete resolution of the septum in the development of the elbow joint [23]. Various theories regarding the formation of this variation have been

suggested. It remains unclear as to what degree the various factors contribute to the formation of the aperture.

Material and Methods

The goal of this study was to describe supratrochlear foramen of the humerus in the Turkish population. There are few studies about it in the Turkish population. A total of 166 dried humeri (83 right side and 83 left side), of which 78 belong to males and 88 to females, were examined to determine the presence of supratrochlear foramen in the Turkish population. The study protocol was approved by the ethics committee of our institution. All measurements were only made on adult bones. These bones were obtained from the Department of Anatomy, Faculty of Medicine and Department of Anthropology, University of Mustafa Kemal, Hatay, Turkey. They were free from any pathological changes and fractures. STF were morphologically and morphometrically analysed. An osteometric board was used to measure the epicondylar breadth (EB) for the sex determination of the humerus. Digital vernier calipers were used to measure the transverse (width) diameter (TD) and vertical (height) diameter (VD) of the STF, the distance of the medial epicondyle to the medial aspect of the STF (MB), and that of the lateral epicondyle to the lateral border of the STF (LB). The shape of the STF was also imaged. In bones where the foramen was not present, opacity and translucency of the supratrochlear septum were noted with the help of transmitted light from posterior to anterior. All measurements are expressed in millimeters. By using these measurements, we calculated minimum, maximum, mean, and standard deviation. SPSS 20.0 version was used for statistical analysis.

Results

The supratrochlear foramen was studied in 166 unpaired Turkish humeri with sex and side known. Measurements were only made on adult bones. The supratrochlear foramen was seen in a total of 18 bones (10.8%). STF was observed in 4 (4.8%) cases on the right side and 14 (16.9%) on the left side. In males, it was seen in 16.7% of cases on the left side and 2.1% of cases on the right side. In females, STF was present on the left side in 17.0% of humeri and 8.6% on the right side (Table 1, Figure 1). In this study, we found most STF were on the left side of both sexes.

In the current study, the vertical diameter for supratrochlear foramen was 4.12 ± 0.98 mm (range 2.7–4.9 mm) on the right side and 4.04 ± 0.9 mm (range 2.1–5.1 mm) on the left side. Transverse diameter was 5.63 ± 0.97 mm (range 4.3–6.5 mm) on the right side and 6.01 ± 1.86 mm (range 2.7–8.9 mm) on the left side.

Table 1. Frequency of supratrochlear foramen and translucent and opaque septum.

Variables	Right side				Total	Left side				Total	Grand total
	Male		Female			Male		Female			
	n	Age (%)	n	Age (%)		n	Age (%)	n	Age (%)		
Foramen	1	2.1	5	13.5	6 (7.1)	5	16.7	7	13.7	12 (14.8)	18 (10.8)
Translucent septum	10	20.8	7	20.0	17 (20.0)	7	23.3	10	19.6	17 (21.0)	34 (20.5)
Opaque septum	37	77.1	25	67.5	62 (72.9)	18	60.0	34	66.7	52 (64.2)	114 (68.7)
Total	48	100.0	37	100.0	85 (100.0)	30	100.0	51	100.0	81 (100.0)	166 (100.0)



Figure 1. Distal end of humerus in human showing the supratrochlear foramen of different shapes from anterior aspect.

In males, the vertical diameter (VD) was 2.72 ± 0.0 mm (range 2.7–2.7 mm) on the right side and 4.26 ± 0.0 mm (range 2.9–5.1 mm) on the left side. Transverse diameter (TD) was 6.52 ± 0.0 mm (range 6.7–6.7 mm) on the right side and 6.7 ± 2.2 mm (range 4.1–8.9 mm) on the left side. In females, the vertical diameter was 4.59 ± 0.36 mm (range 4.2–4.9 mm) on the right side and 3.92 ± 0.93 mm (range 2.1–5 mm) on the left side. The transverse diameter (TD) was 5.34 ± 0.95 mm (range 4.3–6.2 mm) on the right side and 5.64 ± 1.66 mm (range 2.7–7.9 mm) on the left side (Table 2).

The mean distance from medial epicondyle to medial edge of the STF (MB) was 26.1 ± 3.33 mm (range 22.6–30.5 mm) on the right and 25.73 ± 3.37 mm (range 18.9–30.7 mm) on the left side. The mean distance from lateral epicondyle to lateral border of the STF (LB) was 27.3 ± 1.54 mm (range 25.8–29.5 mm) on the right and 27.5 ± 1.5 mm (range 24.9–30.1 mm) on the left side. We observed the position of the STF to be located nearer to the medial epicondyle (Table 2).

The epicondylar breadth (EB) was 60 ± 4.36 mm (range 50.7–69.1 mm) on the right and 58.1 ± 4.07 mm (range 49.7–68 mm) on the left side. The epicondylar breadth was significantly

larger in males (62.7 ± 2.46 mm) than in females ($55.8 \text{ mm} \pm 2.75$) (Table 2)].

The STF was oval, round, triangular, and sieve-like in shape in 13 (7.8%), 2 (1.2%), 2 (1.2%), and 1 (0.6%), respectively, and the oval shape was common on the left side and in females (Table 3).

Translucent septum was found in 34 (20.5%) humeri and opaque septum was seen in 114 (68.7%) humeri. Translucent septum was found in 17 (20.5%) on both sides of the humeri and was very similar in both sexes (Table 1, Figure 2.)

Discussion

The SA is a foramen of the bony septum that separates the olecranon from the coronoid fossae at the distal end of the humerus [24–26]. The supratrochlear foramen (septal aperture) was first described by Meckel in 1825 [27]. The supratrochlear foramen is of great interest to anthropologists, who claim it as important in establishing relationships between humans

Table 2. The different measurements in supratrochlear foramen (minimum, maximum, mean and standart deviation).

Measurements	Right side (mm)				Left side (mm)			
	Male		Female		Male		Female	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Transvers diameter (TD)	6.52	–	5.34	0.95	6.70	2.2	5.64	1.66
	6.5–6.5 (range)		4.3–6.2		4.1–8.9		2.7–7.9	
Vertical diameter (VD)	2.72	–	4.59	0.36	4.26	0.91	3.92	0.93
	2.7–2.7		4.2–4.9		2.9–5.1		2.1–5.0	
EB	62.77	2.56	56.32	3.49	62.68	2.32	55.55	2.09
	59.2–69.2		50.7–68.5		58.4–68.0		49.7–58.9	
MB	30.56	–	24.70	1.95	28.97	1.59	23.93	2.65
	–		22.6–26.5		27.2–30.7		18.9–28.5	
LB	29.54	–	26.65	0.68	28.68	1.23	26.92	1.28
	–		25.8–27.1		27.3–30.1		24.9–29.1	

Table 3. Incidence of different shapes of the supratrochlear foramen.

Variables	Right side				Total	Left side				Total	Grand total
	Male		Female			Male		Female			
	n	%	n	%	n (%)	n	%	n	%	n (%)	
Oval shape	1	2.1	2	5.7	3 (3.6)	4	13.3	6	11.3	10 (12)	13
Round shape	–	–	1	2.9	1 (1.2)	–	–	1	(1.9)	1 (1.2)	2
Triangular shape	–	–	–	–	–	1	3.3	1	1.9	2 (2.4)	2
Sieve-like shape	–	–	–	–	–	–	–	1	1.9	1 (0.6)	1
Total					4					14	18



Figure 2. Showing the translucency of supratrochlear septum.

and lower animals [24], including cattle, rats, dogs, hyenas, and other primates [18,27,28]. According to Hrdlicka, the perforation is very frequent in primates other than man [29]. Lamb

observed that the formation of the STF was more common in ancient peoples and occurs more frequently on the left side and in adolescents, as well as in mature individuals [30]. The

Table 4. Comparative data (in%) of STF in the humerus, race-wise.

No.	Author	Race	Stf Percentage (%)
1.	Akabori	Australians	46.5
2.	Akabori	Egyptians	43.9
3.	Glanville	Africans	47.0
4.	Akabori	Japanese	21.4
5.	Akabori	Koreans	11.0
6.	Ming-Tzu P	Chinese	17.5
7.	Akabori	Mexicans	30.7
8.	Patel	Indians	23.5
9.	Hirsh	Arkanas Indians	58.0
10.	Central Indians	Central Indians	32.0
11.	American Indians	American Indians	29.6
12.	Anupama M	North Indians	26.0
13.	Signal and Rao	South Indians	28.0
14.	Chatterjee	Eastern Indians	27.4
15.	Ananthi et al.	Indians	31.3
16.	Nayak et al.	Indians	34.4
17.	Bhanul et al.	Indians	30.5
18.	Krishnamurthy, Asha, et al.	Indians	23.0
19.	Benfer et al.	American	6.9
20.	Trotter	American Negroes	12.6
21.	Trotter	American Whites	4.3
22.	Mays	English	6.9
23.	Akabori	Italians	9.4
24.	Glanville	Netherlands	6.1
25.	Paraskevas et al.	Greeks	15.8
26.	Papaloucas et al.	Greeks	0.304
27.	Ozturk et al.	Turkish	7.9
28.	Koyun et al.	Turkish	8.6
29.	Cimen et al.	Turkish	12.0
30.	Present study Erdogmus et al.	Turkish	10.8

supratrochlear foramen has, apart from its evolutionary significance, much clinical and surgical importance [18].

There is a wide variation in the rate of the STF occurrence in various human populations. Its incidence varies from close to

0% to almost 60% among different human populations globally [3]. Studies on STF in different populations showed an incidence of 58% in Arkansas Indians [29], 21.7% of African Negroes, 32.5% of South Africans [8], 47% in Tellem [31], 4.3% in White Americans [32], 18.4% in American Negroes [32], 18.1%

Table 5. The statistical data of supratrochlear foramen of humerus in the different studies.

No.	Author	Right side (mean \pm SD, mm)		Left side (mean \pm SD, mm)	
		VD	TD	VD	TD
1	Ananthi	4.48 \pm 1.86	6.50 \pm 2.26	3.98 \pm 1.68	5.82 \pm 2.07
2	Bhanu	5.75 \pm 1.5	6.68 \pm 0.8	4.86 \pm 1.2	6.92 \pm 2.0
3	Blakely	3.79 \pm 1.55	4.76 \pm 2.18	4.18 \pm 1.78	5.94 \pm 2.76
4	Diwan	3.6	5.5	3.8	5.5
5	Krishnamurthy	4 \pm 1.52	5.26 \pm 2.47	4.70 \pm 1.69	6.5 \pm 2.59
6	Nayak	3.81	5.99	4.85	6.55
7	Ozturk	4.56 \pm 1.37	6.70 \pm 1.91	4.95 \pm 1.60	6.86 \pm 2.07
8	Patel	4.77 \pm 1.15	7.31 \pm 1.77	4.99 \pm 1.68	7.03 \pm 1.49
9	Present study	4.12 \pm 0.98	5.63 \pm 0.97	4.04 \pm 0.9	6.01 \pm 1.86

The statistical data of supratrochlear foramen of humerus in the different studies. The values of vertical diameter (VD) and transverse diameter (TD) was expressed in mean \pm SD; mm – millimeters.

in Japanese [16], 17.5% in Chinese [33], 6.9% in Americans [6], and 43.6% in Egyptians [1]. Incidence in European populations was 0.304% in Greeks [22], 6.1% in Netherlands [32], 9.4% in Italians [35]. Incidence in Indian populations showed 27.4% in Eastern Indians [13], 32% in Central Indians [24], 27.56% in North Indians [5], 28% in South Indians [1] and 34.4% in overall Indians [24] (Table 4).

The few previous studies in Turkey reported incidence at 7.9% [26], 8.6% [17], and 12% [17]. We found this ratio was 10.8%, which is similar to the previous Turkish reports (Table 4). Prevalence of septal aperture has been reported to be higher in Indians and Africans than in Europeans and Turks (Table 4).

The frequency of supratrochlear foramen in our study was higher in females and more common on the left side (Table 1). This finding was similar to previous reports [3,5,6,8,17,31,32]. In contrast, Blakely et al. reported that incidence of STF was higher on the left side and in males [10].

In the present study, the prevalence of STF was higher on the left side than the right side (Table 1). Our results also support earlier reports [2,11,14,15,26,27,34,35]. Conversely, Nayak et al. found the presence of STF in 44.5% of cases on the right side [14]. Singhal and Rao found the incidence on both sides was very similar: 27.9% of the right and 27.8% of the left humeri [27].

A number of studies have reported that humeral septal aperture was associated with supracondylar process and there are reports of a greater incidence in males [20,31]. In our study, we did not find septal aperture associated with supracondylar process.

The shape of STF was predominantly oval and it was more common on the left side, similar to previous reports [2,3,9,15,25] (Table 3).

Translucent septum was found in 17 (20.5%) on both sides of the humeri in the Turkish population (Table 1). Bhanu et al. found the translucency in 69 (82.14%) humeri and chiefly on the left side [2]. Krishnamurthy et al. reported an incidence of 66.6%, mostly on the left side [15]. Vasantbhai observed the translucency of septum in 126 (55.8%) on the right side [36] and Veerappan et al. reported 50% [11]. Conversely, according to many authors, incidence of translucency of the septum and STF was higher on the right side [1].

In the present study, the vertical diameter of the supratrochlear foramen was 4.12 \pm 0.98 mm on the right side and 4.04 \pm 0.9 mm on the left side, and the transverse diameter was 5.63 \pm 0.97 mm on the right side and 6.01 \pm 1.86 mm on the left side (Table 2). Table 5 contains comparative statistical data of supratrochlear foramen of humerus in various studies.

In our study we observed that the mean transverse diameter of the STF on the left side is larger than on the right side. This finding was similar to previous reports of Ozturk et al. [26].

In our study, the epicondylar breadth was significantly larger in males (62.7 \pm 2.46 mm) than in females (55.8 \pm 2.75 mm). Ndou et al. reported a mean 56.1 \pm 5.5 mm, significantly larger in males (60.5 mm) than in females (53.4 mm) [8]. The mean distance from medial epicondyle to medial edge of the STF (MB) was 26.1 \pm 3.33 mm on the right side and 25.73 \pm 3.37 mm on the left side, thus the position of STF is located near to the medial epicondyle, especially on the left side. Nayak et al. found 28 mm

on the right and 26.1mm on the left side [14], which agrees with Veereppan et al. [11]. The mean distance from lateral epicondyle to lateral border of the STF (LB) was 27.3 ± 1.54 mm on the right and 27.5 ± 1.5 mm on the left side. Ndou et al. found 26.3 ± 2.9 mm between the STF and the tip of the lateral epicondyle [8].

Some of the mechanisms explaining the cause of STF in the humerus are:

1. It may be an atavistic character [19].
2. It may be worthwhile to investigate this trait in families, with the idea that it may represent an epigenetic character [17].
3. Some authors considered it to be due to mechanical pressure during hyperextension [34].
4. The large olecranon process has been blamed by some authors [4,22].
5. Some believe that STF is formed by resorption from anterior surface of septum [4].
6. STF arises from impingement on humeral septum by coronoid and olecranon processes [37].
7. It was suggested that the generally greater degree of joint hypermobility in females than in males, and in the left than the right upper limb joints, may be a factor behind the greater prevalence of septal aperture in left humeri and in females [37].
8. Hirsh mentioned that the pressure of olecranon process may decrease the blood supply, leading to septal aperture formation [29].
9. Usual mechanism of injury is by hyperextension load on the elbow from falling on an outstretched arm [11].
10. It may be result a disturbance in the calcium metabolism [6].
11. A small flexion angle is associated with high robusticity of the humerus [32]. It has often been noticed that populations which have a high frequency of septum perforation tend also to have a low robusticity of the bones [6].
12. A septal aperture is associated with decreased robustness, smaller humeral diameter, and a narrower canal diameter [12].
13. The possible reason for the presence of the STF in animals is the posture adapted by them during tearing of food [35].
14. Hirdlička pointed out that intermittent pressure would cause hyperemia, resulting in the strengthening of the bony plate (fossa) rather than adsorption [6].
15. It can be explained that it is a phylogenetic characteristic feature frequently found in primates and is suppressed by the stronger limb and exhibited in the weaker limb [2,10].
16. A septal aperture is thought to occur early in childhood from excessive cancellous bone resorption in the distal humerus [12].
17. Hirdlička thought that the bilateral occurrence might suggest gene differences among different populations [31].
18. Mall suggested that the higher occurrence of STF in females may be due to inward curvature of the female elbow angle [3].

Clinical importance:

1. It represents evolutionary aspects of the foramen in addition to its surgical and orthopedic significance [31].
2. Supracondylar fractures account for 75% all injuries in children [9].
3. STF is associated with narrow medullary canal and anterior angulation at the distal humerus. The knowledge of presence of STF may be important for preoperative planning for treatment of supracondylar fractures, especially following traumatic injuries and pathologic fractures, and call for performing antegrade medullary nailing rather than retrograde medullary nailing [17,19,35].
4. The supracondylar fracture of the distal humerus is the most common pediatric fracture in the elbow [37].
5. Awareness of the various shapes and dimensions such as the transverse (TD) and vertical (VD) distance in which this foramen occurs may help avoid misinterpretation of radiographs [8].
9. On x-ray, STF presents as radiolucent areas simulating an osteolytic or cystic lesion, hence knowledge of STF may prevent misinterpretation of X-rays by radiologists [21].
10. Measurements of the epicondylar breadth (EB) will be obtained to shed some light on the gracility of these bones, as the STF is known to be more prevalent in gracile bones than in robust ones [4,6].
11. Knowledge of vertical and transverse diameters of ST helps in orthopedic surgeries [20].
12. A number of studies have suggested that STF may be a hereditary phylogenetic trait with evolutionary significance [2,22].
13. Prevalence of septal aperture, which is higher in populations from India and Africa than in Europeans [4,32].

Conclusions

The present study showed 10.8% STF incidence in the Turkish population, with the left side predominant. Prevalence of septal aperture has been reported to be higher in India and in Africa than in Europeans and Turks (Table 5). We believe that this study will contribute to the literature; anatomical knowledge of STF is beneficial for anatomists, anthropologists, forensic practice, orthopedic surgeons, and radiologists.

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