A comprehensive study of the anatomical variations of the posterolateral tubercle of talus

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Abstract

The aim of our study was to establish the prevalence of the different anatomical variants of the posterolateral tubercle of talus on CT imaging. 1478 ankle CT scans were retrospectively reviewed for the different anatomical variants of the posterolateral tubercle of talus, the type and size of os trigonum. Normal sized lateral tubercle was found in 46.1%, an enlarged posterolateral tubercle (Stieda's process) in 26.1%, os trigonum in 20.5% and almost absent tubercle in 7.3%. A statistically higher prevalence of Stieda's process was found in males while os trigonum was higher in females ($p<0.05$). Among feet with os trigonum, 25.7% were non-articulating and identified as a separate bone located posterior to the posterolateral tubercle of talus and 74.3% of os trigonum were identified as fused to the posterolateral tubercle by synchondrosis or syndesmosis. Additionally, 17.5% of os trigonum were associated with intact lateral tubercle, 53.5% were considered as part of the lateral tubercle and 29.0% were without a lateral tubercle. According to its size, 22.8 % of os trigonum were smaller than 0.5 cm, 55.4% were between 0.5 and 1cm, and 21.8% were larger than 1 cm. No significant differences were found between the different types/sizes of os trigonum according to gender ($p>0.05$). The posterolateral tubercle of talus and its accessory ossicle, the os trigonum, could vary morphologically. The data of this study could be helpful in understanding the clinical problems that could be associated with some of these variants.

Introduction

The posterior process of the talus is made up of two tubercles, the medial tubercle and the lateral tubercle. Between these tubercles is a groove that allows the passage of the flexor hallucis longus tendon from the posterior ankle to enter the tarsal tunnel (Drake, Vogl, & Mitchel, 2015). The lateral tubercle is generally larger and serves as an attachment point for the posterior talofibular ligament and the posterior talocalcaneal ligament (Sarrafian & Kelikian, 2011). An accessory bone, the os trigonum can occur in continuity with the lateral tubercle of talus. It begins to appear between the ages of 8-11 years in boys and 8–10 years in girls as a secondary center of ossification for the posterior process of talus. Normally it fuses with talus within a year (Eastwood, 2002). If the ossicle fails to fuse, it is referred to as the os trigonum. Fusion results in the formation of a prominent lateral tubercle of the posterior talus, termed as a Stieda's process.

A wide variation in the size of the lateral tubercle of talus and the os trigonum is present. Sarrafian and Kelikian classified the lateral tubercle of talus according to its size into: absent, moderate, medium and large (Sarrafian & Kelikian, 2011). Medium and large lateral tubercles were identified in the study of Zwiers et al as an enlarged Stieda's process (Zwiers, Baltes, Opdam, Wiegerinck, & van Dijk, 2018). For the variations of os trigonum, it can be fused with the lateral tubercle by a cartilaginous or fibrous articulation or be a separate fragment not articulating with the posterior talus (Howse, 1982; Mann & Owsley, 1990; Murphy, 2003).

Watson and Dobas described a classification scheme for the anatomical variations of the posterolateral tubercle of talus (Watson C.A., 1976). Type 1 was identified as a normal appearance of the lateral tubercle without clinical consequence. Type 2 is the Stieda's process (an enlarged posterolateral process). Type 3 is the os trigonum, which may be the source of discomfort because of repetitive trauma. Type 4 is a fused os trigonum, which forms a synchondrosis or syndesmosis with the talus.

There is a paucity of work upon the prevalence of the four anatomical variations of the posterolateral tubercle in a single comprehensive study. However, the frequency of occurrence of the os trigonum alone was widely investigated in normal feet and it varies from 2 to 50% (MS Burman & PW Lapidus, 1931; Mann & Owsley, 1990), and a population- specific incidence was also reported for os trigonum (Mann & Owsley, 1990; Zwiers et al., 2018). On the other hand, the frequency of the enlarged posterolateral talar tubercle (Stieda's process) is rarely reported with incidences of 35.7% and 14.7% in the Netherlands and Chinese population, respectively (Fu et al., 2019; Zwiers et al., 2018). The aim of this study was to provide a comprehensive understanding of the anatomical variations of the posterolateral tubercle of talus and to establish their prevalence on CT imaging.

Methods

Ankle CT scans of adolescent and adult patients made between March 2018 and March 2020 were retrospectively reviewed for the different anatomical variants of the posterolateral tubercle of talus and its accessory bone, the os trigonum.

Excluded from the study were patients aged less than 14 years, patients with ankle fracture, instability, avulsion fractures of the tibia, fibula, or lateral tubercle of talus (Shepherd fracture), patients who underwent hindfoot surgery, patients with pathologies including osteolysis, severe arthritis, osteochondritis dissecans, avascular necrosis, and congenital deformations of the ankle joint. This study was approved by the Academic Research Council and the Ethics Committee. Age and gender data were obtained from hospital medical records.

CT scans of 1,478 patients (860 men and 618 women) with 701 left and 777 right feet were included. The anatomical variations of the lateral tubercle of talus were assessed by two researchers independently. Four variants for the lateral tubercle of talus were distinguished (Fig. 1): 1: almost absent, 2: normal tubercle, 3: Stieda's process (enlarged posterolateral tubercle) and 4: os trigonum. Similar to the study of Zwiers et al, we defined medium and large lateral tubercles according to Sarrafian and Kelikian classification as an enlarged Stieda's process (Sarrafian & Kelikian, 2011; Zwiers et al., 2018).

According to the articulation of os trigonum with the posterolateral tubercle, two types were distinguished using multiplanar reformatted images (MPR): separate bone located posterior to the posterolateral tubercle of talus (Type 1) and os trigonum fused to the posterolateral tubercle by synchondrosis or syndesmosis (Type 2). The axial CT images were reconstructed with a slice thickness of 3 mm with reconstruction at 1 and 0.4 mm, and multiplanar reformatted images were obtained with reconstruction. Based on its relation with the posterolateral tubercle in the axial plane, three types of os trigonum were distinguished according to Zwier et al classification (Zwiers et al., 2018): Type A: os trigonum with intact posterolateral tubercle, Type B: os trigonum as part of the posterolateral tubercle and Type C: os trigonum without posterolateral tubercle (Fig. 2). Based on the os trigonum size (measured in the axial plane), three groups were distinguished: smaller than 0.5 cm, between 0.5 and 1cm, and larger than 1 cm (Zwiers et al., 2018).

Statistical Analysis

GraphPad Prism version 6.04 for Windows (GraphPad Software, La Jolla, CA) was used. The anatomical variations of the posterolateral tubercle were compared between genders (male vs. female) and sides (right vs. left) using Chi Squared test. In addition, the anatomical variations of os trigonum was compared between genders using Chi Squared test.

Using a sample of 50 CT scans, inter-rater reliability was analyzed using the *Cohen's* kappa to assess the consistency between the two investigators. A third investigator was consulted in case of disagreement in identifying different variants of the posterolateral tubercle and the type of os trigonum. The significance threshold was set at the value of $p \leq .05$.

Results

The average age was 33.7 (range, 14–63) years. Of the patients, 58.2% were males. The prevalence of different anatomical variants of the posterolateral tubercle was identified as: almost absent (7.3%), normal tubercle (46.1%), Stieda's process (26.1%), and os trigonum (20.5%). The prevalence of Stieda's process was statistically higher in males while os trigonum was statistically higher in females ($p<0.05$). No significant difference was found between sides (Table 1).

Prevalence of type and size of os trigonum was shown in Table 2. Among 303 feet with os trigonum, 25.7% (78/303) were identified as Type 1 and 74.3% (225/303) were identified as Type 2. Additionally, Type A was identified in 17.5% (53/303), Type B in 53.5% (162/303) and Type C in 29.0% (88/303) (Figure 2). No significant difference was found between the two types of os trigonum according to gender ($p>0.05$) (Table 2).

Regarding the size of os trigonum, 22.8% (69/303) was smaller than 0.5 cm, 55.4% (168/303) was between 0.5 and 1cm, and 21.8% (66/303) was larger than 1 cm. No significant difference was found between the different sizes of os trigonum according to gender ($p>0.05$) (Table 2).

Inter-rater agreement (kappa statistics) over identification of the different anatomical variants of the posterolateral tubercle (except for Stieda's process) and types of os trigonum was perfect (kappa > 0.9). Inter-rater agreement for defining an enlarged Stieda's process was *substantial* with a kappa of 0.79.

Discussion

In our study, we examined the prevalence of different anatomical variants of the posterolateral tubercle of talus using CT scans. In the 1478 CT scans examined, the most common variant was the normal sized tubercle (46.1%), followed by Stieda's process (26.1%), and os trigonum (20.5%). An almost absent tubercle was the least common variant (7.3%). A higher prevalence of Stieda's process was found in males while os trigonum was higher in females suggesting that bony union with the posterior talus is more likely to occur in males.

There is a wide variation in the reported incidence of the os trigonum in previous studies. The lowest incidence reported in the literature was 1.7% (Mann & Owsley, 1990). On the other hand, the highest incidence was reported by Burman and Lapidus (M. Burman & P. Lapidus, 1931). They studied 1000 feet X-rays and reported a high occurrence of 50% but only 6% of them were truly separated. In the study of Zwiers et al using 1256 foot and ankle CTs, the presence of os trigonum, size and type were assessed, and a high incidence of 32.5% was reported (Zwiers et al., 2018). In addition, the most common type of os trigonum in their study was type B (50.3%-46.8%), where the os trigonum was identified as part of the posterolateral tubercle, and 57% of the os trigonum was between 0.5 and 1.5 cm. These findings are comparable to our results (Table 2). However, we studied the prevalence of different anatomical types and sizes of os trigonum according to gender and no significant differences were found. A population-specific incidence was also reported for os trigonum. Os trigonum was not found in a cohort of Native Americans and Inuits (Mann & Owsley, 1990). Additionally, in the study of Zwiers et al performed in Netherlands, eight different ethnicity groups classified according to the country of birth or the country of birth of the patient's parents were included. Afro-Caribbean/Surinamese/Central African origin was associated with a lower rate of occurrence of an os trigonum (Zwiers et al., 2018). In our previous work, the incidence of os trigonum in nonathletic patients with sprained ankles was assessed. The incidence of os trigonum was 20.4% of sprained ankles, with a higher incidence in females (Kalbouneh et al., 2019).

The different morphological variants of os trigonum described in this study were also previously identified in a CT based study of a Chinese population (Fu et al., 2019). Three basic types of os trigonum based on the mode of connection were identified; Type 1 was a single bone that was not connected to talus, type 2 was connected to the posterior talar process by a hyaline cartilage, and type 3 was the Stieda's process. Similar to our results, Stieda's process was more common than os trigonum, and the connected form of os trigonum is more common than the separate form.

Little knowledge on the exact occurrence of Stieda's process is available. This may be attributed to the lack of a standard definition for the enlarged posterolateral tubercle. In the study of Zwier et al, Stieda's process was found in about one-third of the patients without os trigonum (Zwiers et al., 2018). In another CT based study of a Chinese population, Stieda's process was identified in 14.7% of patients (Fu et al., 2019).

An understanding of the anatomy is fundamental for recognizing the occurrence of the related diseases that could be caused by the different anatomical variants. Posterior ankle impingement (PAIS) is a condition characterized by posterior ankle pain in plantarflexion. It is usually aggravated by repetitive plantarflexion and can result from either an acute injury or simple overuse (Ribbans, Ribbans, Cruickshank, & Wood, 2015; Russell, Kruse, Koutedakis, McEwan, & Wyon, 2010; Sofka, 2010). Eighty- one percent of the pathologies causing PAIS were reported to be osseous in origin and os trigonum accounted for 47% of these cases while Stieda's process accounted for only 4% (Ribbans et al., 2015). Zwiers et al reported a higher prevalence (46.4%) of os trigonum in patients with posterior impingement complaints using CT images (Zwiers et al., 2018). In a recent study evaluating the prevalence of os trigonum using ankle MRI, os trigonum was found in 63.3% in patients with PAIS (Ozer & Yildirim, 2019).

In our study, most of os trigonum were of a fused type (74.3%). The fused type of os trigonum could be at higher risk for developing symptoms compared to a separate ossicle. Usually the os trigonum is asymptomatic; however, symptoms such as pain and swelling can occur particularly during sporting activities requiring repetitive forced plantarflexion of the foot (Kudas et al., 2016; Ribbans et al., 2015). Repetitive plantarflexion/dorsiflexion may result in degeneration or tear of the synchondrosis posing the fused type of os trigonum at higher risk for developing symptoms. The anatomical variations of os trigonum should be taken into consideration in our population especially in patients with posterior impingement complaints. The repetitive plantarflexion/dorsiflexion is a continuous requirement during Muslim prayer which may cause disruption of the synchondrosis between the os and the talus or causing compression of the ossicle/ Stieda's process against the tibia (Kalbouneh et al., 2019). Further studies are recommended to assess the prevalence of different anatomical variants of the posterolateral tubercle of talus in patients diagnosed clinically and radiologically with PAIS, and to evaluate the risk posed by different anatomical variants to PAIS.

Conclusion

The anatomy of the posterolateral tubercle of talus is variable. An understanding of this anatomy is fundamental for recognizing the occurrence of the different symptoms that could be associated with them. Orthopedic surgeons should be aware of these variations during ankle arthroscopic procedures.

Declarations

Ethical approval and consent to participate:

This study was approved by the Academic Research Council and the Ethics Committee of Jordanian Royal Medical Services and The University of Jordan.

Availability of data and materials:

Please contact authors for data requests (Heba Kalbouneh PhD –email address: heba.kalbouneh@ju.edu.jo).

Conflict of interests

The research did not receive any specific grant from funding agencies in the commercial or not-for-profit sectors. The authors do not have conflicts of interest.

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Author's contribution:

HK: Manuscript writing, design of the work, supervision and project development. MA: Manuscript editing and data analysis design. MBH: Acquisition of data and interpretation. HA: Acquisition of data and interpretation. YM: Data analysis and literature review. TM: Data analysis and literature review. TB: Data analysis and literature review. OA: Project development, validation and management. All authors drafted the work, approved the version to be published; and agreed to be accountable for all aspects of the work.

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Tables

Table 1: The anatomical variations of the posterolateral tubercle of talus According to Gender and Side

	All; N=1478; N (%)	Male; N=860; N (%)	Female; N=618; N (%)	Right; N=777; N (%)	Left; N=701; N (%)
Type 1	108 (7.3)	65 (7.6)	43 (7.0)	60 (7.7)	48 (6.8)
Chi-square		.191		.416	
P value		.662^{ns}		.519^{ns}	
Type 2	681 (46.1)	392 (45.6)	289 (46.8)	354 (45.6)	327 (46.6)
Chi-square		.202		.176	
P value		.653^{ns}		.675^{ns}	
Type 3	386 (26.1)	248 (28.8)	138 (22.3)	201 (25.9)	185 (26.4)
Chi-square		7.891		.052	
P value		.005*		.819^{ns}	
Type 4	303 (20.5)	155 (18.0)	148 (23.9)	162 (20.8)	141 (20.1)
Chi-square		7.746		.122	
P value		.005*		.727^{ns}	

*significant, ^{ns}not significant.

Table 2: Prevalence of type and size of os trigonum according to gender

	All; N=303; N (%)	Male; N=153; N (%)	Female; N=150; N (%)
Type of os trigonum			
Type 1	78 (25.7)	43 (28.1)	35 (23.3)
Type 2	225 (74.3)	110 (71.9)	115 (76.7)
Chi- square		.902	
P value		.342^{ns}	
Type A	53 (17.5)	28 (18.3)	25 (16.7)
Type B	162 (53.5)	87 (56.9)	75 (50.0)
Type C	88 (29.0)	38 (24.8)	50 (33.3)
Chi- square		2.666	
P value		.264^{ns}	
Size of os trigonum			
Smaller than 0.5 cm	69 (22.8)	37 (24.0)	32 (21.5)
Between 0.5 and 1 cm	168 (55.4)	81 (52.6)	87 (58.4)
Larger than 1 cm	66 (21.8)	36 (23.4)	30 (20.1)
Chi- square		1.040	
P value		.595^{ns}	

*significant, ^{ns} not significant.

Type 1 &2: Based on its articulation with the posterolateral tubercle

Type A, B & C: Based on its relation with the posterolateral tubercle in the axial plane

Figures

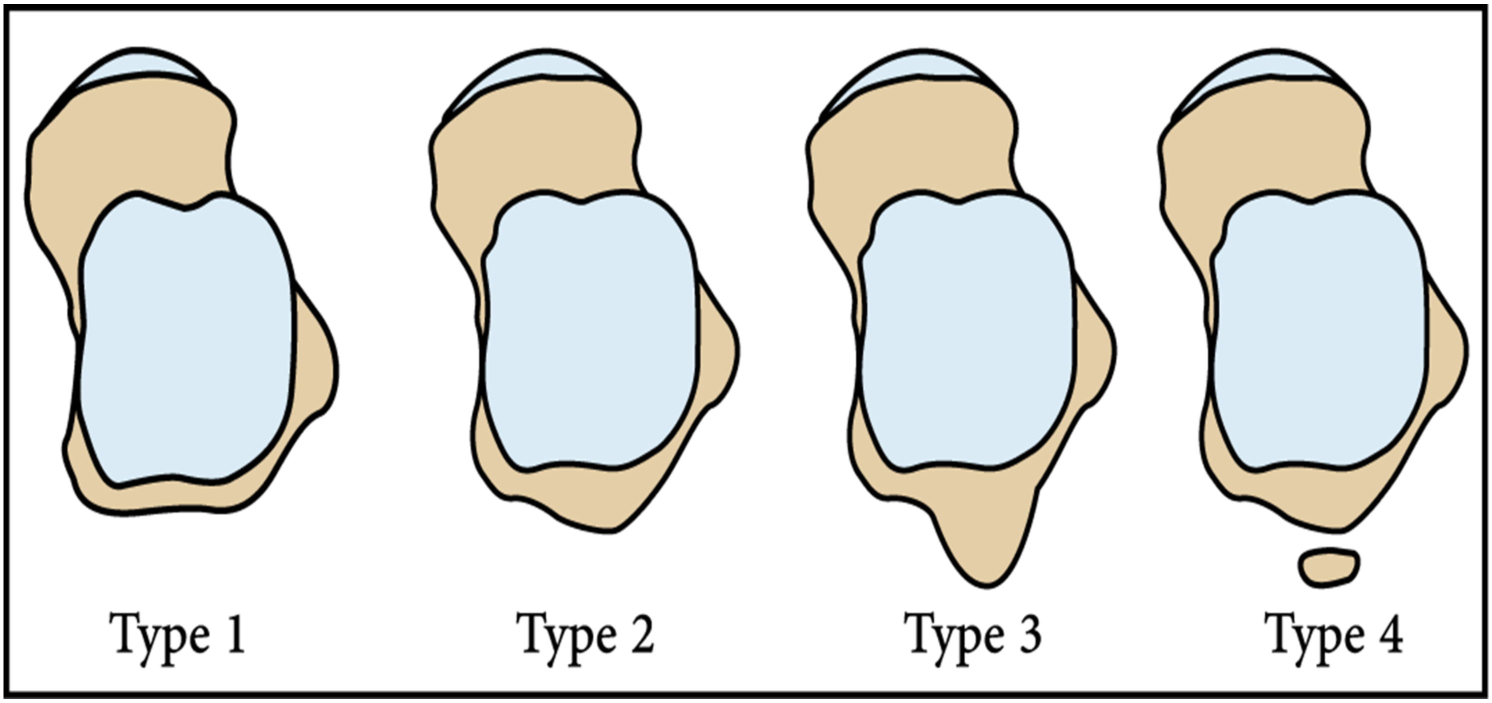

Figure 1

Variations in the posterolateral tubercle of talus. 1: Almost absent, 2: Normal, 3: Enlarged (Stieda's process), and 4: Os trigonum.

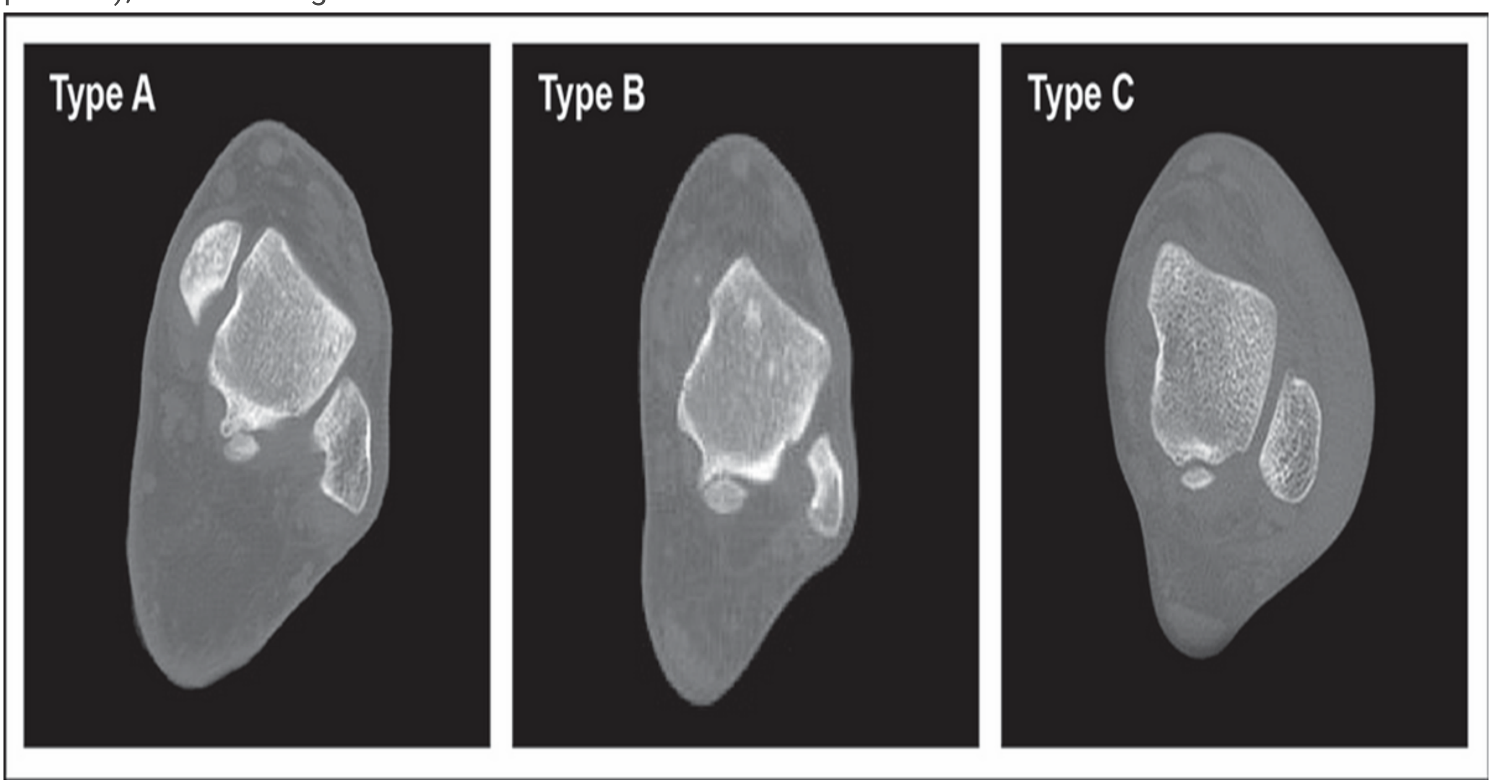

Figure 2

Axial multiplanar reformatted images of ankle computed tomography showing different types of os trigonum according to Zwier et al classification (Zwiers et al., 2018): Type A: os trigonum with intact posterolateral tubercle, Type B: os trigonum as part of the posterolateral tubercle and Type C: os trigonum without posterolateral tubercle.