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ORIGINAL ARTICLE

Os calcaneus secundarius, a relevant differential diagnosis to fracture or pseudarthrosis of processus anterior of the calcaneus: a CT morphologic description

Robert Hennings[1] · Peter Voigt[2] · Thomas Kahn[2] · Christoph Josten[1] · Annette B. Ahrberg[1]

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Abstract

Purpose A fracture or a pseudarthrosis of the processus anterior calcanei (PAC) as well as a traumatized Os calcaneus secundarius (OCS) is often overlooked. A clinical or conventional radiological differentiation of these is uncertain. Therefore, a CT scan is recommended. The aim of the study was to identify CT morphological differentiators between OCS and pathologies of PAC.

Methods All CT scans at our trauma center level I from 2010 to 2014, which imaged the entire foot, performed after acute trauma or postoperative control were retrospectively re-examined for OCS, other accessory ossicles (oAOS), fracture or pseudarthrosis of PAC and analyzed for specifiers.

Results In 611 CT examinations, 14 (2.3%) accessory ossicles (AOS) at the PAC were detected. 12 (86%) were identified as typical OCS and 2 (14%) as oAOS. 56 (9.2%) pathologies were detected. Of these, 44 (79%) were declared as fractures and 12 (21%) as pseudarthrosis. 7 OCS (58%) and 25 (46%) of the pathologies were not mentioned in the initial CT reports. The main differentiators of OCS to fracture of PAC were the anteromedial localization into a concave notch at the calcaneal facet at PAC and the continuous corticalization. With increasing size, radiological osteoarthritic signs at the OCS were frequent ($p \leq 0.05$).

Conclusions The study confirms that AOS or pathologies at the PAC often are not exactly described in CT report. In the context of foot trauma, attention should be paid to this region. Based on the presented differentiation criteria, a precise distinction can be made with the help of a CT.

Keywords Os calcaneus secundarius · Pseudarthrosis · Fracture · Processus anterior of the calcaneus · Calcaneonavicular coalition · Accessory ossicle

Introduction

Pathologies of the processus anterior calcanei (PAC) are often overlooked in initial plain radiography and can be a cause for persisting or chronic pain in the foot [18, 19, 30]. In addition to a fracture of the PAC or a pseudarthrosis (PA), an Os calcaneus secundarius (OCS) must also be considered [9, 13, 14, 16].

OCS is a rare, precisely defined accessory ossicle typically on the anterior facet of the PAC, located between the PAC, the cuboid, the talus and the navicular bone and was first described by Stieda in 1869 [20, 26, 28, 34, 35]. The term Os calcaneus secundarius was introduced by Piersol and Dwight in 1907 [28]. Its prevalence in conventional radiographies is 0.6–2% [15, 36]. There is no conclusive pathogenesis of OCS. While some authors assume that OCS develops from a secondary center of ossification, others describe it as a calcification of a part of the calcaneonavicular ligament or traumatization of the immature cartilaginous calcaneus [20, 25]. At the anteromedial PAC where the OCS is typically located, the lateral calcaneonavicular ligament and the medial, dorsolateral and plantar calcaneocuboidal

✉ Robert Hennings
robert.hennings@medizin.uni-leipzig.de

[1] Department of Orthopedics, Traumatology and Plastic Surgery, University Hospital Leipzig, Liebigstr. 20, Leipzig 04103, Germany

[2] Department of Diagnostic and Interventional Radiology, University Hospital Leipzig, Liebigstr. 20, Leipzig 04103, Germany

ligament attach, which are necessary for the stability of the transverse tarsal joint [21, 29, 31]. There is no evident correlation between the size of OCS and the presence of discomfort or pain, therefore, the clinical relevance is difficult to assess.

After acute trauma, OCS can mimic a fracture, can be traumatized or asymptomatic, otherwise a fracture or pseudarthrosis of PAC can be the undetected cause of chronic or persistent pain after a minor or major trauma [8, 9, 13, 14, 24, 33]. After a distortion trauma of the ankle joint or foot, acute injuries like an avulsion at the PAC should be anticipated [8, 37]. A fracture of the PAC should be considered after a painful hyperdorsiflexion of the foot due to a missed step [8]. It was shown that these injuries can be expected in approximately 5% of the conventional plain radiography [18]. While a fracture usually presents with clinical signs like pain on palpation of the sinus tarsi and an accompanying hematoma on the lateral foot, PA and OCS are more difficult to assess. The symptoms are frequently misdiagnosed as a simple lateral ankle sprain like a rupture of the anterior talofibular ligament [18, 37]. Pathologies of the PAC as well as OCS are mostly detectable in dorsoplantar and oblique X-ray, but accurate differentiation is difficult with these. Therefore, an MRI or CT examination, sometimes a scintigraphy is necessary for a reliable diagnosis [16, 17, 22, 27, 31]. A precise diagnosis is essential for the choice of treatment. To our knowledge, there are some studies from the early to the middle of twentieth century describing accessory ossicles at the PAC in conventional X-rays [8, 37]. But there is no study with a larger sample size describing OCS morphology with cross-sectional diagnostics like MRI or CT in living individuals [6, 16, 22, 31, 36]. Only a few case reports exist with inconsistent nomenclature [9, 16, 38]. The aim of this study was to describe the OCS morphology in CT scans, demonstrate distinguishing features in comparison to the fracture or a pseudarthrosis of PAC and finally establish a simple classification of accessory ossicles at the PAC.

Subjects and methods

Prior to this study, approval of the local ethics committee review board was obtained (309-15-24082015). All ethical and legal aspects in the conduct of studies in humans were observed and certified by the ethics committee.

All CT scans from 2010 to 2014 in our Level 1 Trauma Center that image the entire foot and were performed after acute trauma or for postoperative controls were retrospectively re-examined for OCS, a fracture or pseudarthrosis of the PAC as well as other accessory ossicles around the PAC. The term "anterior processus (processus anterior) of the calcaneus" (PAC) was used according to Golder's publication and includes the anterior third of the calcaneus [11]. All radiology reports were analyzed whether an OCS was mentioned.

Definition of OCS was based on the publications of Stieda, Mellado, Anderson and R.W. Mann as a precisely defined accessory ossicle with a crescent-shaped notch at the anterior calcaneal facet, located between the calcaneus, cuboid, talus and the naviculare bone [1, 20, 22, 34]. OCS consists of a roughened medial border at the site of synchondrosis with the calcaneus and a smooth dorsal surface for articulation with the talus because OCS comprises the anterior talar facet of the PAC (Fig. 1a–c) [1, 20, 22, 28, 34]. The size of OCS was determined according to R. W. Mann in the transversal reconstruction (Fig. 1a) [20]. Furthermore, small rounded ossicles with a continuous cortex in direct relation to the PAC were assessed as other accessory ossicles (oAOS) (Fig. 2a–c).

According radiological studies, fractures were defined as a cortical interruption at both fracture sides without sclerosis signs or osteoarthritic signs (Fig. 3a–c) [8, 37]. An irregular cortical interruption with partial or total sclerosis signs was defined as PA (Fig. 4a–c).

Synchondrosis-space narrowing and/or incongruence, subchondral sclerosis as well as subchondral cysts were defined as osteoarthritic signs (OA).

All CT scans were performed without administration of intravenous contrast medium. Patients were positioned supine and feet-first. Images were acquired using a multidetector CT scanner (iCT 256, Philips, Netherlands). Routine scan parameters included a tube current of 150 mA, a tube voltage of 100 kV with a collimation of 64×0.625 mm. Pitch was 0.329 with a rotation time of 0.5 s. Multiplanar reformations were reconstructed in slice thickness of 1–2 mm in axial, sagittal and coronal orientations. Whenever requested by the referring trauma surgeon, additional 3D reconstructions were reconstructed from raw data. The scans were re-examined independently and retrospectively by a board-certified orthopedic surgeon as well as a board-certified radiologist.

All pseudonymous patient data were stored in a database (Excel, Microsoft; SPSS, Version 24, IBM). The statistical evaluation was carried out using SPSS (Version 24, IBM SPSS, Chicago, IL, USA). Independent samples with normal distribution were calculated using the t test ($p \leq 0.05$), and frequency differences were calculated using the Chi square test ($p \leq 0.05$). The level of significance for statistical analysis was set at $p \leq 0.05$.

Results

In 611 CT scans, 14 (2.9%) structures around the PAC were classified as an accessory ossicle (AOS). Of these, 12 (86%) fulfilled the criteria of an OCS according to Strieda as well

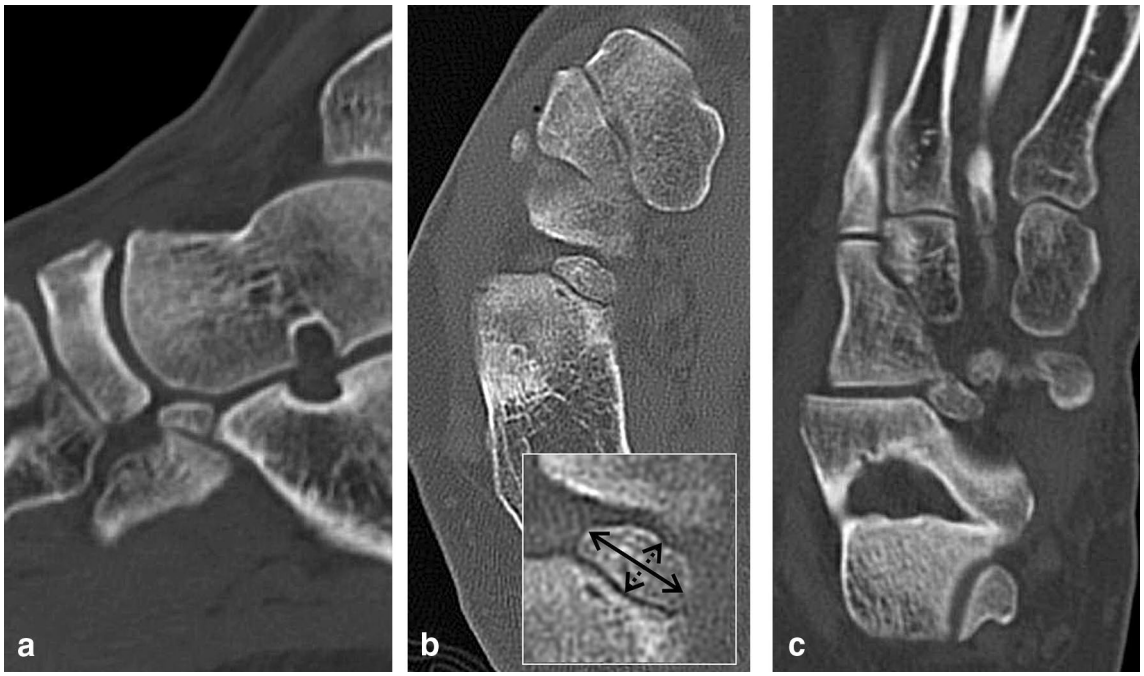

Fig. 1 **a**–**c**: CT scan of a 47-year-old female illustrates the measurement of an Os calcaneus accessorius (OCS) (**a**). The main features of an OCS are crescent-shaped notch at the anterior calcaneal facet with a pea-shape (**a**), located between the calcaneus, cuboid, talus and the naviculare bone (**b**–**c**). In addition, it demonstrates signs of arthrosis in the area of the notch with sclerosis and cysts (**a**)

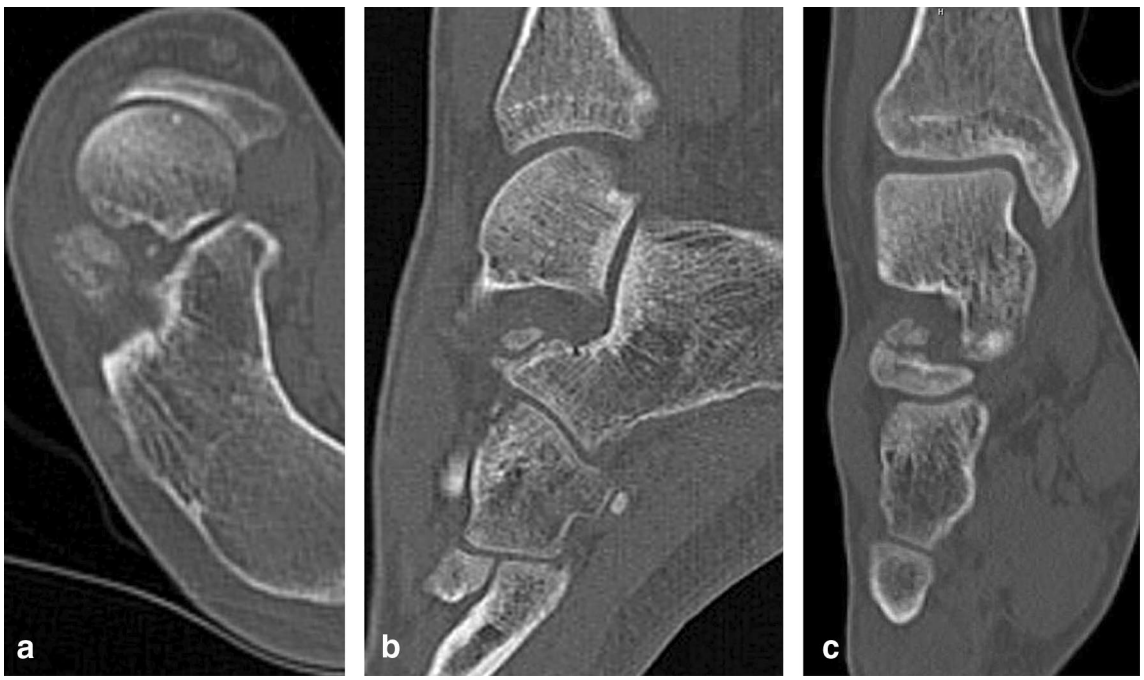

Fig. 2 **a**–**c** CT scan of a 26-year-old male illustrates an accessory ossicle superior the processus anterior calcanei without joint surface involvement

Fig. 3 **a**–**c** CT scan of a 45-year-old female illustrates the characteristics of a fracture of the processus anterior calcanei: a cortical interruption at both fracture sides without sclerosis or osteoarthritic signs. Note the inclusion of the entire cross-section and the concomitant avulsion at the lateral part of the naviculare bone as a sign of acute trauma (**a**)

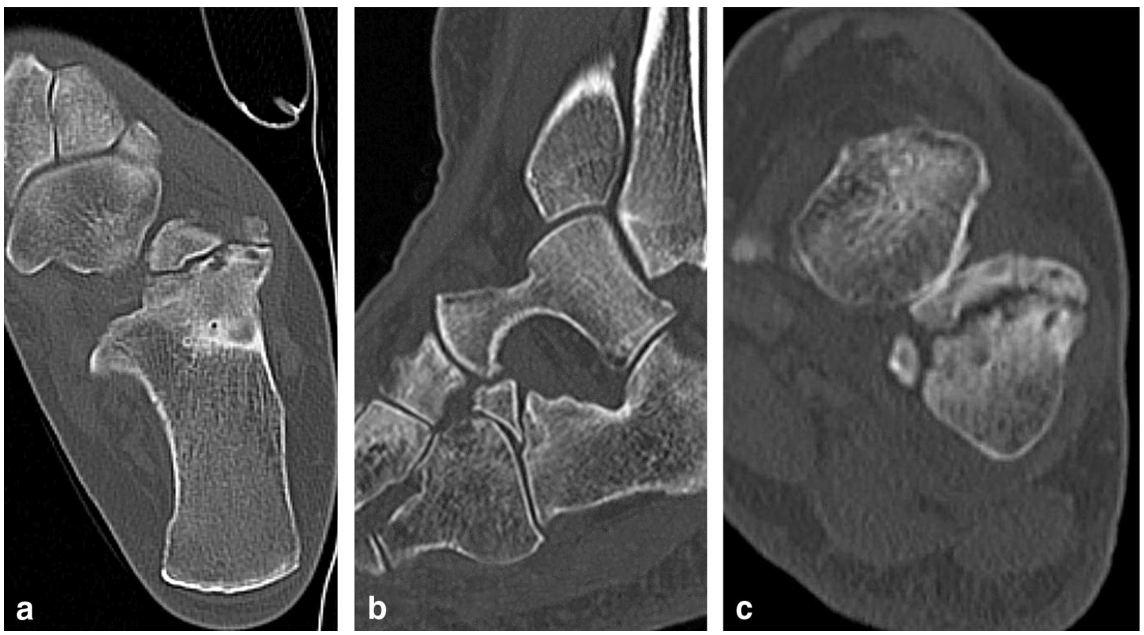

Fig. 4 **a**–**c** CT scan of a 53-year-old female illustrates the characteristics of a pseudarthrosis of the processus anterior calcanei: an irregular cortical interruption with sclerosis signs (**a**) and a triangular shape (**b**). Note the extent over the entire cross-section (**a** and **c**)

as Mellado and 2 (14%) were declared as other accessory ossicles (oAOS) around the PAC. Eleven out of 12 OCS were located typically at the anteromedial calcaneal facet between PAC, talus, navicular bone and cuboid (Fig. 1a–b). One OCS was located median at the calcaneal facet at the PAC. All OCS comprised the anterior cartilaginous joint

surface of the PAC (Table 1). The biggest OCS of this series was 19.5 mm × 10 mm in transversal and 7 mm × 7 mm in sagittal reconstruction. The smallest was 3 mm × 2 mm in transversal and 2 mm × 1 mm in sagittal reconstruction. We did not detect any osteoarthritic (OA) signs frequently in the smallest OCS, but with increasing size OA signs were significant frequent ($p \leq 0.05$; Figs. 1a, 5a). Among OCS with a diameter less than 10 mm in transversal reconstruction, 2 out of 6 showed OA signs. In the group with a diameter more than 10 mm in transversal reconstruction, OA signs were detectable in all 6 cases (Table 1).

Just 6 (43%) out of 14 AOS were mentioned in the initial CT reports and 7 (58%) of the OCS were not mentioned in the initial CT reports. Only in one case of OCS, the right nomenclature was used. The other OCS were paraphrased as a "small peripheral osseous structure", "a small apophysis ventral to the medial calcaneus", "small bone medioventral to the calcaneus" or "an older imposing fracture of PAC".

Table 1 Mean radiological characteristics of accessory ossicles around the processus anterior calcanei

Case	Size at the transversal reconstruction (mm)	Localization at the PAC	Mentioned in CT report	Osteo-arthritic signs	Classification	Type
1	3×2	Anteromedial	Yes	No	OCS	I
2	3×2	Lateral	No	No	oAOS	II
3	4×3	Superior	Yes	No	oAOS	II
4	4.5×5	Median	No	Yes	OCS	I
5	6×3	Anteromedial	No	No	OCS	I
6	8×4	Anteromedial	No	No	OCS	I
7	8.5×3	Anteromedial	Yes	No	OCS	I
8	9×5	Anteromedial	No	Yes	OCS	I
9	10×5	Anteromedial	Yes	Yes	OCS	I
10	10×7	Anteromedial	Yes	Yes	OCS	I
11	11.5×7	Anteromedial	No	Yes	OCS	I
12	12.5×7.5	Anteromedial	No	Yes	OCS	I
13	13.5×5.5	Anteromedial	Yes	Yes	OCS	I
14	19.5×10	Anteromedial	No	Yes	OCS	I

OCS Os calcaneus secundarius, *oAOS* other accessory ossicle

Fig. 5 **a–c** CT scan of a 27-year-old male demonstrates a bilateral bipartite Os calcaneus accessorius

The smallest OCS was mentioned in the CT report whereas the biggest was not.

Two AOS without compromising the joint surface at the PAC were detected. One was located lateral and one superior to the PAC and was termed as oAOS (Fig. 2a–c).

Based on the criteria for fractures and pseudarthrosis, retrospectively, 56 (9.2%) pathologies were detected in 611 CT scans, thereof 44 (79%) declared as fractures and 12 (21%) as pseudarthroses (PA) of the PAC. 25 (45%) of all pathologies at the PAC identified in the study were not described in the initial CT report, 15 (34%) out of 44 fractures and 10 (83%) out of 12 of PA.

The average age of patients with an OCS at the imaging diagnostics was 38 (range 16–67) years with a gender distribution of 7 men and 5 women. In 3 cases, both feet were reconstructed among which one bilateral bipartite OCS was found with an anteromedial and an anterolateral part (Fig. 5a–c). The indications to perform the CT scans and the main diagnoses were heterogeneous and are listed in Table 2.

Discussion

With 12 OCS (2.9%) in 611 CT scans, this study comprises the highest number of OCS in an imaging study. In the recent literature, only a few case reports on OCS exist which describe the configuration with a CT-scan, MRI or detected the OCS in conventional plain radiography [6–9, 16, 33]. Greater numbers of OCS were described in anatomical samples [1, 20]. All fractures of the PAC seen in this study fulfilled standard fracture signs such an interrupted corticalis and an irregular morphology at both fracture sides, a more triangular shape in sagittal reconstruction and often comprise the whole breath of PAC in transversal reconstruction (Fig. 3a–c), which can be used as differentiators to the OCS. Avulsions are shell-like and frequent at the dorsolateral aspect of the PAC with also interrupted corticalis.

The present study shows that osteoarthritic signs like subchondral calcification and cysts are no clear features to differentiate OCS and PA, especially if the size of the structure is more than 10 mm in the transversal reconstruction (Figs. 1a, 4a, c, 5a). In addition, the presence of multiple fragments is not definite for PA. We found one bipartite bilateral OCS (Fig. 5a–c). Reliable distinguishing features for PA are the more triangular configuration in sagittal reconstruction and extension over the whole mediolateral extension of PAC (Fig. 4a–c) and for the OCS, the anteromedial location, crescent-shaped notch at the anterior calcaneal facet and the more square base configuration in sagittal reconstructions (Fig. 1a–c).

As far back as 1990, R.W. Mann described a terminological confusion which is maintained in more recent literature [9, 16, 20]. OCS should not be confused with other accessory ossicles (oAOS) like calcaneus accessorius or os in sinus tarsi [26, 35]. The present data and the review of the literature show that pathologies such as a fracture or a pseudarthrosis of PAC as well as OCS were often overlooked and the nomenclature introduced by Piersol and Dwight in 1907 is not widely used [28]. Given the persisting terminological confusion, we suggest a new classification of accessory bones around the PAC, which considers the localization as well as the anatomy and may be helpful

Table 2 Demographics and clinical characteristics of patients with accessory ossicles around the processus anterior calcanei

Age at CT scan (years)	Male in years, mean Female in years, mean	36 (range 16–67) 39 (range 26–58)
		n
Sex	Male	9
	Female	5
Indication for the CT scan	Suspicioned fracture of the foot	4
	Analysis of the distal tibiofibular syndesmosis postoperatively after stabilization	4
	Analysis of an ankle fracture/pilon preoperatively	3
	Osteoarthritis	1
	Complex tibia fracture	1
	Suspected PAC fracture	1
Main diagnosis	Ankle fracture	5
	Ankle sprain	3
	Avulsion at the PAC	2
	Complex tibia fracture	1
	Metatarsal II fracture	1
	Intact foot	1
	Complex pilon fracture	1

for treatment decision. Accessory ossicles comprising the articular facets of the PAC (Fig. 1a–c) are classified as AOS type I. AOS Type II involves all ossicles which are around the PAC without comprising the articular facets (Fig. 2a–c).

The discrimination and exact terminology of OCS, oAOS, fracture or PA of PAC is essential for the choice of treatment. The main CT morphological criteria of OCS are the anteromedial localization (11 out of 12 cases), a pea-shaped well-corticalized ossicle, a crescent-shaped notch at the anteromedial calcaneal facet which comprises the articular surface of the calcaneus and are corresponding to the cadaver studies and the Definition of Steida (Fig. 1a–c) [1, 34]. After an acute trauma with haematoma and pain located at the sinus tarsi, a traumatized OCS can only be differentiated to a limited extent from a fracture or a pre-existing pseudarthrosis (PA) of the PAC in conventional X-ray diagnostics. In these cases, an MRI imaging a bone marrow edema (BME) in the fracture area may be indicated [22]. MRI has proven to be effective in differentiating between traumatic lesions and anomalies [2, 32]. However, traumatized OCS or PA may also be associated with a BME and make differentiation unclear [22]. Therefore, in the case of acute trauma, in addition to conventional X-ray, a CT scan and the application of the presented CT morphological differentiators could be used instead of an MRI to ensure a valid diagnosis. In the past, scintigraphy was used as a diagnostic tool to visualize traumatized areas through increased metabolic activity [10]. Due to the complex anatomy of the foot and the resulting reduced diagnostic precision, scintigraphy was widely replaced by MRI [2, 5, 23]. In individual cases, this can be considered as quantitative bone SPECT/CT with Tc-99m HDP to differentiate between OCS and PA with metabolic active and inactive processes [3, 12].

The clinical relevance and therapy of a symptomatic OCS, as defined in the current literature, are uncertain. Mellado et al. disputed any clinical significance [22]. In the literature, there are a few articles about conservative as well as operative options. To make therapy recommendations, an exact and homogenous nomenclature is required, as suggested above. Krapf et al. published a case with symptomatic OCS treated successfully by surgical excision. After more in-depth assessment of the CT scan pictures of the published case, the so-called OCS does not conform with the definition of Stieda's OCS [16, 34]. The ossicle does not comprise the anterior facet of the PAC, it is extraarticular and located at the sinus tarsi like in one oAOS of the present study [16] [4]. It is comparable to an accessory calcaneus, as described by Wünschel et al. and Baghla et al. and reveals the terminological confusion described by R.W. Mann [4, 9, 20, 38]. Controversially, the patient of Heikel et al. who was conformed with the definition of Stieda was not painless after excision of the OCS and soft tissue interposition [13]. Some authors reported about patients with symptomatic OCS who were free of pain after conservative treatment [8, 9]. In the synopsis of the few literatures and the demonstrated data, AOS Type I, which comprises the articular surface and attachment points of stabilizing ligaments of the transverse talar joint, should, therefore, not be resected [13]. AOS Type II may lead to a bony conflict with reduced and painful motion with increasing size. Surgical excision seems to be a treatment option but a conservative treatment should be the first step therapy [4, 16].

This study has some limitations. It is a retrospective image analysis, and the number of patients is low due to the rarity of OCS and the patient population was very heterogeneous. However, it is the largest CT-analyzed cohort of living individuals. The clinical relevance of the OCS was evaluated only in the context of the sparse literature.

Conclusions

The present study confirms that accessory ossicles in the area of the PAC are usually not subject to standard terminology and often do not receive sufficient attention. It was possible to work out CT morphological differentiators between OCS, other accessory ossicles, a fracture or pseudarthrosis at the PAC. An easy-to-use classification of accessory ossicles at the PAC in relation to the local anatomy could be offered.

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References

1. Anderson T (1988) Calcaneus secundarius: an osteo-archaeological note. Am J Phys Anthropol 77:529–531
2. Angoules AG, Angoules NA, Georgoudis M, Kapetanakis S (2019) Update on diagnosis and management of cuboid fractures. World J Orthop 10:71–80

3. Bae S, Kang Y, Song YS, Lee WW (2019) Maximum standardized uptake value of foot SPECT/CT using Tc-99 m HDP in patients with accessory navicular bone as a predictor of surgical treatment. Medicine 98:e14022
4. Baghla DPS, Shariff S, Bashir WA (2010) Acquired cavo-varus deformity caused by an accessory calcaneus: a case report and literature review. Skeletal Radiol 39:193–197
5. Bohnsack M, Gossé F, Rühmann O, Wenger K (1999) The value of scintigraphy in the diagnosis of pseudarthrosis after spinal fusion surgery. J Spinal Disord 12:482–484
6. Bulut MD, Yavuz A, Bora A, Gokalp MA, Ozkacmaz S, Batur A (2014) Three-dimensional CT findings of os calcaneus secundarius mimicking a fracture. Case Rep Radiol 2014:537062
7. Ceroni D, de Coulon G, Spadola L, de Rosa V, Kaelin A (2006) Calcaneus secundarius presenting as calcaneonavicular coalition: a case report. J Foot Ankle Surg 45:25–27
8. Dachtler IW (1931) Fractures of the anterior superior portion of the os calcis due to indirect violence. Am J Roentgenol 25:629–631
9. Ersen O, Akyildiz F, Ozyurek S, Sivrioglu AK (2013) Os calcaneus secundarius mimicking fracture. BMJ Case Rep 2013
10. Geyer M, Sander-Beuermann A, Wegner U, Wirth CJ (1993) Stressreaktionen und Stressfrakturen beim Leistungssportler. Ursachen. Diagnostik und Therapie. Unfallchirurg 96:66–74
11. Golder WA (2004) Anterior process of the calcaneus: a clinical-radiological contribution to anatomical vocabulary. Surg Radiol Anat 26:163–166
12. Ha S, Hong SH, Paeng JC et al (2015) Comparison of SPECT/CT and MRI in diagnosing symptomatic lesions in ankle and foot pain patients. Diagnostic performance and relation to lesion type. PLoS One 10:e0117583
13. Heikel HV (1962) Coalitio calcaneo-navicularis and calcaneus secundarius: a clinical and radiographic study of twenty-three patients. Acta Orthop Scand 32:72–84
14. Hodge JC (1999) Anterior process fracture or calcaneus secundarius: a case report. J Emerg Med 17:305–309
15. Kleinberg S (1917) Supernumerary bones of the foot: an X-Ray study. Ann Surg 65:499
16. Krapf D, Krapf S, Wyss C (2015) Calcaneus secundarius-a relevant differential diagnosis in ankle pain: a case report and review of the literature. J Med Case Rep 9:127
17. Kürklü M, Köse O, Yurttas Y, Oguz E, Atesalp AS (2010) Anterosuperior calcaneal process fracture or OS calcaneus secundarius. Am J Phys Med Rehabil 89:522
18. Lindner HO, Kaufner HK (1986) Der Bänderriss im lateralen Chopartgelenk. Zentralblatt für Chirurgie 111:1250–1254
19. Main BJ, Jowett RL (1975) Injuries of the midtarsal joint. J Bone Joint Surg Br 57:89–97
20. Mann RW (1990) Calcaneus secundarius: description and frequency in six skeletal samples. Am J Phys Anthropol 81:17–25
21. Melao L, Canella C, Weber M, Negrao P, Trudell D, Resnick D (2009) Ligaments of the transverse tarsal joint complex: MRI-anatomic correlation in cadavers. Am J Roentgenol 193:662–671
22. Mellado JM, Ramos A, Salvado E, Camins A, Danus M, Sauri A (2003) Accessory ossicles and sesamoid bones of the ankle and foot: imaging findings, clinical significance and differential diagnosis. Eur Radiol 13:L164–L177
23. Miller TT (2002) Painful accessory bones of the foot. Semin Musculoskelet Radiol 6:153–161
24. Naumann E (1955) Aussergewohnlich grosser Calcaneus secundarius mit gelenksahnlicher Verbindung zum Calcaneus und Naviculare. RöFo 83:413
25. Niederecker K (1951) Pathologische Veränderungen des Fußskeletts bei Plattfüßen anhand eines größeren Operationsmaterials. Z Orthop 80:97–128
26. O'Rahilly R (1953) A survey of carpal and tarsal anomalies. J Bone Joint Surg 35:626–642
27. Ochman S, Evers J, Raschke MJ (2013) Frakturen des Processus anterior calcanei. Oper Orthop Traumatol 25:579–591
28. Piersol GA (1907) Human anatomy. JB Lippincott, Philadelphia
29. Rammelt S, Grass R, Schikore H, Zwipp H (2002) Verletzungen des Chopart-Gelenks. Unfallchirurg 105:371–385
30. Renfrew DL, el-Khoury GY (1985) Anterior process fractures of the calcaneus. Skeletal Radiol 14:121–125
31. Robbins MI, Wilson MG, Sella EJ (1999) MR imaging of anterosuperior calcaneal process fractures. Am J Roentgenol 172:475–479
32. Schuler MK, Dammann F, Schewe B, Winter E, Weise K (2003) Unterscheidungsmerkmale der Os-naviculare-Pseudarthrose gegenuber dem Os naviculare accessorius. Unfallchirurg 106:73–76
33. Stauss J, Connolly LP, Perez-Rossello J, Treves ST (2003) Skeletal scintigraphy of possible os calcaneus secundarius. Clin Nucl Med 28:424–425
34. Stieda CHL (1869) Über secundäre Fusswurzelknochen. Arch Physiol Wissensch Med 108:111
35. Trolle D. (1948) Accessory bones of the human foot. A Radiological, Histoembryological, Comparative-anatomical, and Genetic Study. Copenhagen, Munksgaard 194–195
36. Tsuruta T, Shiokawa Y, Kato A et al (1981) Radiological study of the accessory skeletal elements in the foot and ankle. Nihon Seikeigeka Gakkai Zasshi 55:357–370
37. Warrick CK, Bremner AE (1953) Fractures of the calcaneum, with an atlas illustrating the various types of fracture. J Bone Joint Surg Br 35-B:33–45
38. Wunschel M, Wulker N, Kluba T (2007) Progressive pes adductus caused by an accessory calcaneus: a case report. FootAnkle Int 28:838–840