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The relationship of MRI findings and clinical features in symptomatic and asymptomatic os naviculare

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AIM: To investigate the relationship between magnetic resonance imaging (MRI) findings and clinical features in patients with os naviculare.

MATERIALS AND METHODS: All patients with a foot or ankle MRI study showing an os naviculare were identified from a specialist orthopaedic hospital between 2014 and 2017. A total of 110 patients with 133 os naviculare were included. The MRI features were recorded, as well as the presence or absence of medial foot pain and/or tenderness over the navicular tuberosity. Fisher's exact test was used for categorical data and unpaired *t*-tests for continuous data. Specificity and sensitivity were calculated for MRI features.

RESULTS: There were 80 female and 30 male patients with a mean age of 46±1.7 years at time of MRI (range 11–90.6 years). There was a significant correlation between os naviculare oedema (p=0.008) and navicular tuberosity oedema (p=0.001) with a history of medial foot pain. There were significant associations between mean age (p=0.003), type of os naviculare (p=0.004), os naviculare oedema (p<0.001), navicular tuberosity oedema (p=0.001), and soft tissue oedema (p=0.01) with examination findings of tenderness over the navicular tubercle. Oedema of the os naviculare, navicular tuberosity, or soft tissues were found to have a high specificity but low sensitivity for medial foot pain and tenderness.

CONCLUSION: When present, certain MRI findings indicate that an os naviculare is likely to be a cause of patient symptoms, but when absent they do not exclude the possibility of it causing symptoms.

Introduction

Accessory ossicles of the foot and ankle are a common incidental finding, the os naviculare being one of those most frequently encountered with a prevalence of 4–21% in the general population.[1–6] This accessory ossicle was first described by Bauhin in 1605.[7] It is more common in females[8] and bilateral in 50–90% of cases.[8,9] In a small proportion of patients (~1%) it can be a cause of morbidity,[2,10] presenting with chronic or acute-on-chronic medial foot pain with swelling, erythema, and tenderness about the navicular tuberosity.[6,9,11]

The Geist classification proposed in 1914 outlines three types of os naviculare.[12] Type 1 is a 2–6 mm sesamoid bone within the distal tibialis posterior tendon, accounting for 30% of cases.[5,8,13] Type 2 is a 8–12 mm triangular or heart-shaped ossicle united to the navicular tuberosity by a

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synchondrosis, accounting for 50–60% of cases.[5,8,9] Type 3 is believed to be a fused type 2 os naviculare, resulting in a prominent navicular tuberosity (cornuate navicular).[3,14,15] Type 2 os naviculare are responsible for 70% of all symptomatic cases.[16]

There are multiple theories as to the aetiology of signs and symptoms. Firstly, they are commonly believed to result from repetitive tension and sheering stress across the synchondrosis caused by the pull of the tibialis posterior tendon.[13] Histopathological studies have confirmed cartilage proliferation and bone remodelling at the synchondrosis, indicating chronic stress.[3,9,17] Secondly, the navicular bone has a critical role in maintaining the medial longitudinal arch.[18] Disruption of the natural biomechanics of the foot is also thought to be a contributor.[6] Finally, direct pressure on the os naviculare is also felt to cause symptoms.

Recently, it has been reported that symptomatic os naviculare demonstrate altered signal intensity (SI) with a bone marrow oedema pattern on magnetic resonance imaging (MRI)[3,17,19]; however, the presence or absence of such changes in asymptomatic os naviculare has not been investigated, and therefore, it is not known if such oedema is specific to a symptomatic os. In the present study, MRI findings were correlated to clinical features for both symptomatic and asymptomatic os naviculare in a large group of patients, thereby aiding radiologists and clinicians to determine whether an os naviculare is an incidental finding, or pathological and potentially responsible for patient symptoms.

Materials and methods

The study was approved by the local research and development committee, with no requirement for informed consent.

All patients who underwent a foot and/or ankle MRI study at a specialist orthopaedic hospital between April 2014 and April 2017 were included. Those with a finding of os naviculare were identified by performing a search of the radiology reports using the picture archiving and communication system (PACS). Phrases used included “os naviculare”, “accessory navicular”, and “os tibiale externum”. A total of 133 feet of 110 patients were found to have an os naviculare on MRI within the time period stated.

All of the MRI studies were reviewed by a senior consultant musculoskeletal radiologist with over 22 years’ experience, who was blinded to the clinical features. The MRI studies were all obtained at 3 T using a dedicated extremity coil with the following protocols[1]: ankle: (a) sagittal proton density weighed fast spin echo (PDW FSE), repetition time (TR)=3,382 ms, echo time (TE)=30 ms, 2.5 mm section thickness, 16 cm field of view (FOV); (b) sagittal short tau inversion recovery (STIR), TR=5,496 ms, TE=60 ms, inversion time (TI)=180 ms, 2.5 mm section thickness, 16 cm FOV; (c) axial PDW FSE, TR=3,585 ms, TE=25 ms, 2.5 mm section thickness, 15 cm FOV; (d) axial spectral attenuated inversion recovery (SPAIR), TR=3,754 ms, TE=30 ms, 2.5 mm section thickness, 15 cm FOV; (e) coronal SPAIR, TR=3,766 ms, TE=30 ms, 2.5 mm section thickness, 16 cm FOV.[2] Foot: (a) sagittal T2W TSE, TR=4,837 ms, TE=100 ms, 2.5 mm, 18 cm FOV; (b) axial PDW FSE; TR=4,000 ms, TE=30 ms, 2.5 mm section thickness, 18 cm FOV; (c) axial SPAIR; TR= 4,000 ms, TE= 30 ms, 2.5 mm section thickness, 18 cm FOV; (d) coronal PDW FSE; TR= 4,855 ms, TE= 30 ms, 2.5 mm section thickness, 10 cm FOV; (e) coronal SPAIR; TR= 4,000 ms, TE= 30 ms, 2.5 mm section thickness, 10 cm FOV.

MRI findings recorded included type of os naviculare (Types 1–3), os naviculare oedema, navicular tuberosity oedema, adjacent soft-tissue oedema, which were all manifest by increased signal intensity (SI) on the SPAIR or STIR sequences. Additionally, in cases of Type 2 os naviculare, the presence of fluid, cysts, and degenerative changes at the synchondrosis were noted. Other possible causes of medial foot pain were also recorded.

The electronic patient records (EPR) were then reviewed by a member of the foot and ankle unit who was unaware of the MRI findings. The presenting history and examination findings were recorded, specifically the presence or absence of medial foot pain and examination findings of tenderness over the navicular tuberosity.

Two sets of statistical analysis were performed, firstly comparing MRI findings with the presence or absence of medial foot pain, and secondly with the presence or absence of tenderness over the navicular tuberosity. All variables, except for patient age, were categorical in nature, and therefore, Fisher’s exact test was used. Patient age, being a continuous variable was compared using an unpaired *t*-test. Specificity and sensitivity were calculated for os naviculare oedema, navicular tuberosity oedema, and soft-tissue oedema for the relationship to medial foot pain and tenderness over the navicular tubercle. A 95% confidence interval (CI) was determined using the exact binomial method. For all analysis, a p-value of <0.05 was considered significant.

Results

The study group included 80 female and 30 male patients with a mean age of 46±1.7 years (range 11–90.6 years) at the time of MRI. Of these, 23 had undergone imaging of both feet making a total of 133 feet with an accessory navicular. Regarding type of os, 44 cases were classified as Type 1 (Fig 1a and b), 74 as Type 2 (Fig 1c and d) and 15 as Type 3 (Fig 1e and f).

Table 1 gives details of the relationship between the absence or presence of medial foot pain and MRI findings. Medial foot pain was recorded in 45 patients (34%). There was a significant association between os naviculare oedema (p=0.008; Fig 2a and b) and navicular tuberosity oedema (p=0.001; Fig 2c) with medial foot pain. The presence of os naviculare oedema and navicular tuberosity oedema was higher in cases with medial foot pain compared to asymptomatic cases. When os naviculare oedema was present, 67% of cases had medial foot pain. Conversely, when os naviculare oedema was absent, 70% of cases reported no

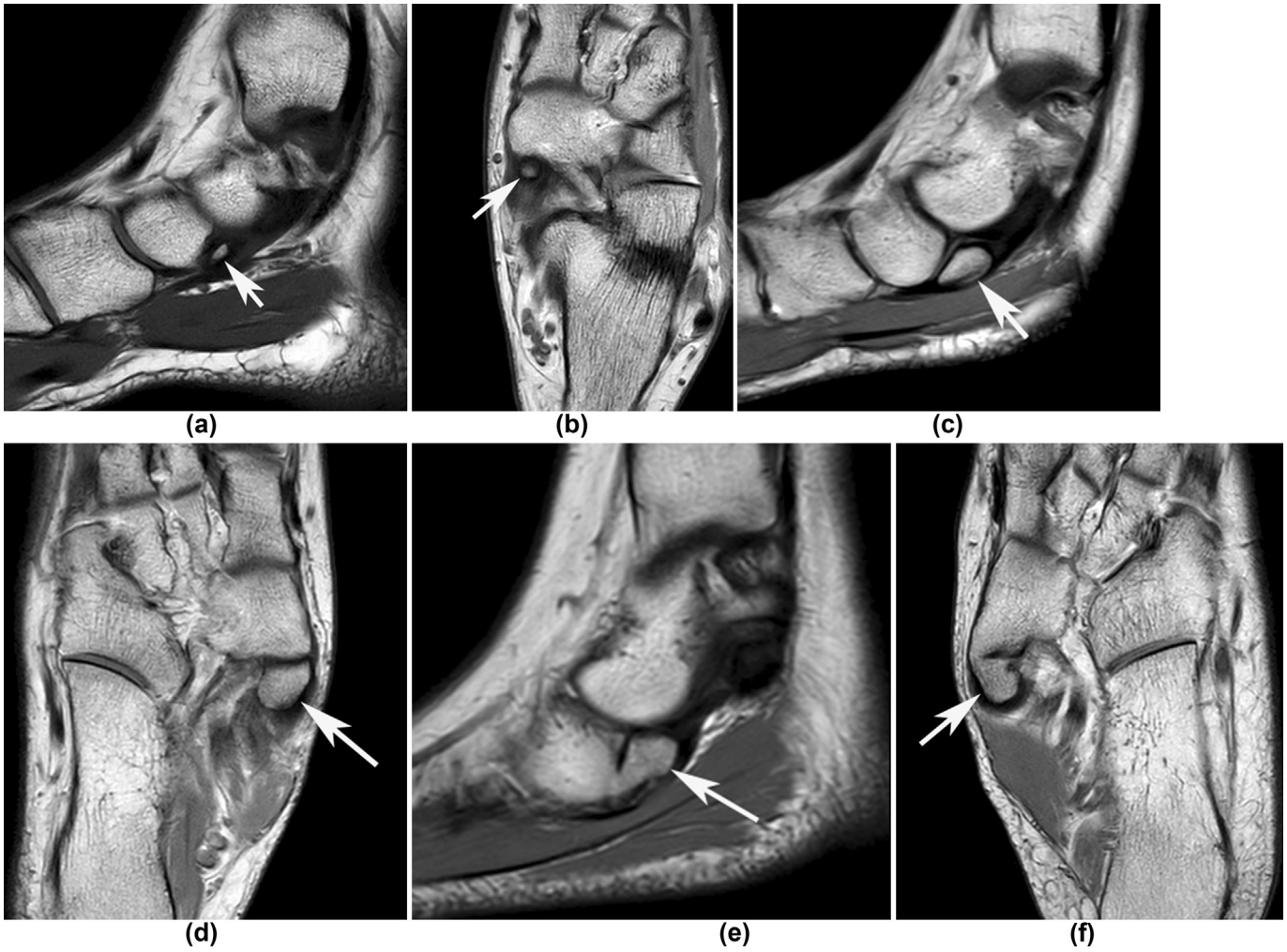

Figure 1 (a) Sagittal and (b) axial PDW FSE MRI images showing a Type I os naviculare (arrows). (c) Sagittal and (d) axial PDW FSE MRI images showing a Type II os naviculare (arrows). (e) Sagittal and (f) axial PDW FSE MRI images showing a Type III os naviculare (arrows).

medial foot pain. When navicular tuberosity oedema was present, 77% of cases had medial foot pain. Conversely, when navicular tuberosity oedema was absent, 71% of cases reported no medial foot pain. There was a difference in the mean age of patients with and without medial foot pain, with younger patients tending to present with medial foot pain, but this was of borderline statistical significance ($p=0.05$). No other MRI findings were found to be significantly associated with medial foot pain.

Table 2 gives details of the relationship between MRI findings and the absence or presence of tenderness over the navicular tuberosity. Tenderness over the navicular tuberosity was recorded in 16% and was absent in 83%. No data were available for one case (case no. 7347819; Table 2). There was a significant association between mean age ($p=0.003$), type of os naviculare ($p=0.004$), os naviculare oedema ($p<0.001$), navicular tuberosity oedema ($p=0.001$), and soft-tissue oedema ($p=0.01$) with tenderness over the navicular tuberosity. Younger patients, with a mean age of 34.2 years (range 12.3–64.8 years), tended to present with tenderness over the navicular tuberosity in comparison to older patients, with a mean age of 48.3 years (range 11–90.6 years) who tended to be asymptomatic. Patients with Type 2 and Type 3 os naviculare were more likely to experience tenderness over the navicular tuberosity, this recorded in 23% and 20% respectively. Almost all cases (98%) of Type 1 os naviculare were asymptomatic. The presence of os naviculare oedema, navicular tuberosity oedema, and soft-tissue oedema was more common in patients with tenderness over the navicular tubercle compared to asymptomatic cases. When os naviculare oedema was present, 60% had tenderness over the navicular tubercle. Conversely, when os naviculare oedema was absent, 88% experienced no tenderness. When navicular tuberosity oedema was present, 54% had tenderness over the navicular tubercle. Conversely, when navicular tuberosity oedema was absent, 94% reported no tenderness. Finally, when soft-tissue oedema was present (Fig 3), 37% had tenderness over the navicular tubercle. Conversely, when soft-tissue oedema was absent, 87% reported no tenderness. No other MRI features were found to be significantly associated with navicular tubercle tenderness ($p>0.05$).

Other MRI findings that could potentially cause medial foot pain were as follows: tibialis posterior pathology

Table 1
Clinical and magnetic resonance imaging features in the absence and presence of medial foot pain.

Variable	Category	No foot pain n=88 (66%)	Foot pain n=45 (34%)	p-Value
Age[a] (years)	-	48.3±19.2	41.4±20.2	0.05
Sex	F	53 (66%)	27 (34%)	1.00
	M	35 (66%)	18 (34%)	
Type of os naviculare	1	34 (77%)	10 (23%)	0.12
	2	46 (62%)	28 (38%)	
	3	8 (53%)	7 (47%)	
Oedema os naviculare	No	83 (70%)	35 (30%)	0.008
	Yes	5 (33%)	10 (67%)	
Oedema navicular bone	No	84 (71%)	34 (29%)	0.001
	Yes	3 (23%)	10 (77%)	
Oedema soft tissues	No	77 (68%)	36 (32%)	0.20
	Yes	10 (53%)	9 (47%)	
Fluid in synchondrosis[b]	No	39 (66%)	20 (34%)	0.13
	Yes	6 (43%)	8 (57%)	
Cysts in synchondrosis[b]	No	28 (60%)	19 (40%)	0.80
	Yes	17 (65%)	9 (35%)	
Synchondrosis type[b]	Irregular	18 (62%)	11 (38%)	0.53
	Osteophytes	4 (44%)	5 (56%)	
	Smooth	23 (66%)	12 (34%)	

[a] Mean ± standard deviation reported.
[b] Analysis of type 2 os naviculare cases only.

Table 2
Clinical and magnetic resonance imaging features in the absence and presence of tenderness over the navicular tubercle.

Variable	Category	No tenderness n=111 (84%)	Tenderness n=21 (16%)	p-Value
Age[a] (years)	-	48.3±19.0	34.2±20.0	0.003
Sex	F	66 (84%)	13 (16%)	1.00
	M	45 (85%)	8 (15%)	
Type of os naviculare	1	42 (98%)	1 (2%)	0.004
	2	57 (77%)	17 (23%)	
	3	12 (80%)	3 (20%)	
Oedema os naviculare	No	105 (90%)	12 (10%)	<0.001
	Yes	6 (40%)	9 (60%)	
Oedema naviculare bone	No	103 (88%)	14 (12%)	0.001
	Yes	6 (46%)	7 (54%)	
Oedema soft tissues	No	98 (87%)	14 (13%)	0.01
	Yes	12 (63%)	7 (37%)	
Fluid in synchondrosis[b]	No	45 (76%)	14 (24%)	1.00
	Yes	11 (79%)	3 (21%)	
Cysts in synchondrosis[b]	No	36 (77%)	11 (23%)	1.00
	Yes	20 (77%)	6 (23%)	
Synchondrosis type[b]	Irregular	23 (79%)	6 (21%)	0.33
	Osteophytes	5 (56%)	4 (44%)	
	Smooth	28 (80%)	7 (20%)	

[a] Mean±standard deviation reported.
[b] Analysis of Type 2 os naviculare cases only.

(n=20), plantar fasciitis (n=10), tarsal coalition (n=7), midfoot osteoarthritis (n=3), spring ligament injury (n=2), deltoid ligament injury (n=1), and talonavicular osteoarthritis (n=1). Of the patients with tibialis posterior tendon pathology, four had insertional tendinosis.

In the relationship to medial foot pain, os naviculare oedema and navicular tuberosity oedema had a specificity of 94% (95% CI: 87–98%) and 97% (95% CI: 90–99%) respectively, but sensitivity was 22% (95% CI: 11–37%) and 23% (95% CI: 11–38%) respectively. In the relationship to tenderness over the navicular tuberosity, os naviculare oedema, navicular tuberosity oedema, and soft-tissue oedema had a specificity of 95% (95% CI: 89–98%), 94% (95% CI: 88–98%) and 89% (95% CI: 82–94%) respectively, while sensitivity was 43% (95% CI: 22–66%), 33% (95% CI: 15–57%) and 33% (95% CI: 15–57%) respectively.

Discussion

This study is the largest MRI series of symptomatic and asymptomatic os naviculare, and has confirmed that certain MRI findings are highly specific to only symptomatic os naviculare, such features being largely absent in asymptomatic cases. In particular, os naviculare oedema and

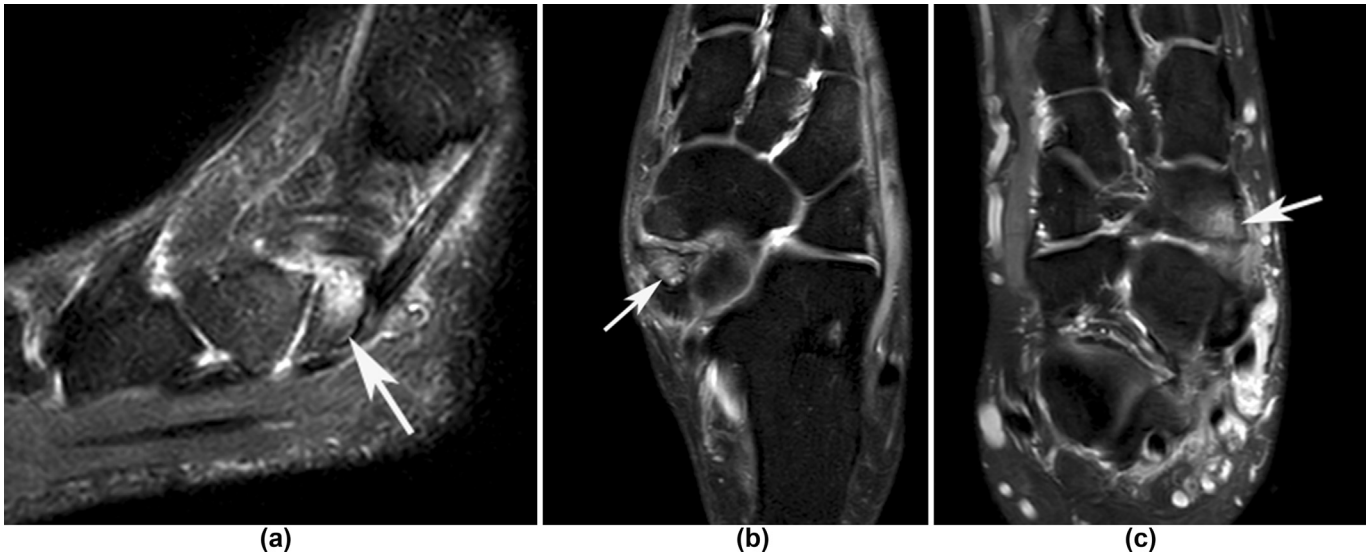

Figure 2 (a) Sagittal and (b) axial SPAIR MRI images showing an oedematous Type II os naviculare (arrows). (c) Axial SPAIR MRI images showing an oedematous navicular tuberosity (arrows).

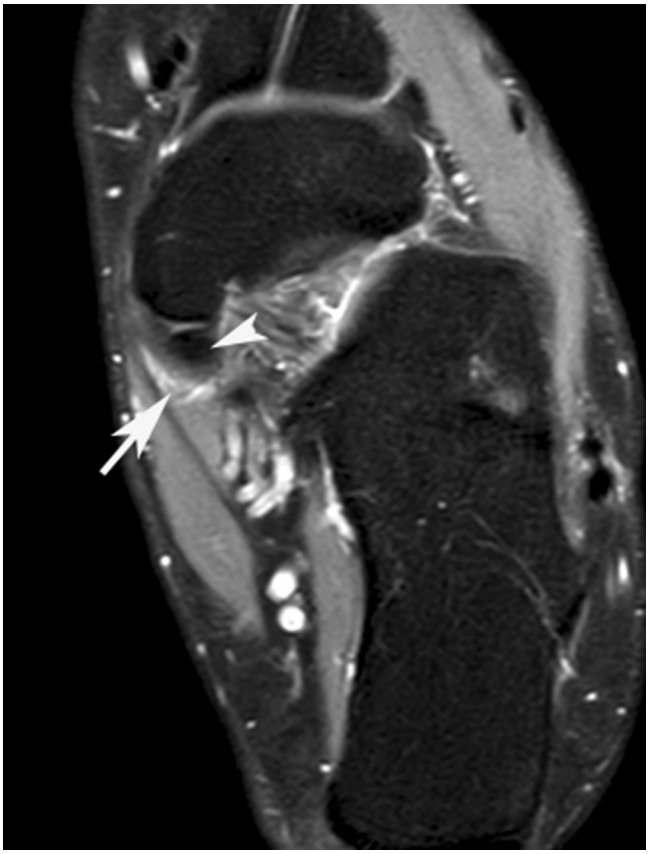

Figure 3 Axial SPAIR MRI image showing soft-tissue oedema (arrow) overlying an otherwise uncomplicated os naviculare (arrowhead).

navicular tuberosity oedema were significantly associated with medial foot pain, while os naviculare oedema, navicular tuberosity oedema, and soft-tissue oedema were significantly associated with tenderness over the navicular tuberosity. There was also a significant association between Type 2 and 3 os naviculare, and younger patients presenting with tenderness over the navicular tuberosity.

In agreement with published literature,[18] type 2 os naviculare were responsible for 62% of cases with medial foot pain, and 81% of cases with tenderness over the navicular tuberosity. There was also a predominance of os naviculare in female patients (60%), as has been previously reported.[8]

Very few studies have explored the relationship of MRI findings to clinical features in both symptomatic and asymptomatic os naviculare. Most relevant to the present study is that conducted by Miller *et al.* in which MRI of both feet of seven patients with radiographically proven os naviculare and clinical features of unilateral medial foot pain was undertaken.[3] Four of those patients had bilateral os naviculare allowing the asymptomatic foot to act as a control. They reported that in five patients with pain directly over the navicular region, a bone marrow oedema pattern was found in the os naviculare. Three of those patients also demonstrated an oedema pattern in the navicular bone. Two of the seven patients had vague, diffuse foot pain. These two patients and the four asymptomatic os naviculare demonstrated no oedema pattern in either the os naviculare, navicular tubercle or the soft tissues. These reported findings are in agreement with the present study.

Takahashi *et al.* investigated the MRI findings in 10 adolescent patients presenting with pain over the navicular tuberosity.[20] They found seven of these patients to have Type II os naviculare and three to have no os naviculare present. They reported a bone marrow oedema pattern in all symptomatic navicular bones, irrespective of whether an os naviculare was present or not. In cases of os naviculare, there was oedema of both the os naviculare and the navicular bone. In the five patients who also had an asymptomatic os naviculare, the oedema pattern was absent on the painless side, as with the present findings. Finally, they identified that the intensity of the bone marrow oedema diminished with symptom alleviation.

A study conducted by Choi *et al.* reported MRI findings in 17 patients with medial foot pain and surgically proven Type II os naviculare.[21] In all cases, a bone marrow oedema pattern was present in the os naviculare and synchondrosis, and also in the adjacent soft tissues. As is the consensus in the current literature, this is believed to indicate inflammation, cartilage destruction, and osteonecrosis.

Chiu *et al.* performed a study using Tc-99m MDP bone scintigraphy,[16] which included 13 patients with 13 symptomatic and 10 asymptomatic os naviculare. They identified increased uptake in all of the symptomatic os naviculare as well as in 50% of the asymptomatic lesions. They concluded that a negative bone scan could exclude the presence of a symptomatic os, but because of a lack of specificity a positive bone scan should be interpreted with caution. In the current study, certain MRI findings, such as os naviculare oedema, navicular tuberosity oedema, and soft-tissue oedema, were found to be highly specific to only symptomatic os naviculare, with these findings being largely absent in asymptomatic cases.

Although this is the largest report of MRI in both symptomatic and asymptomatic os naviculare, it is not without limitations. Firstly, the retrospective nature of the study made it difficult to obtain complete data, and therefore, adequately assess presenting symptomatology. The number of patients with tenderness over the navicular tuberosity was comparatively low. Finally, the study employed a single senior musculoskeletal radiologist; however, the MRI appearances of bone and soft-tissue oedema are easily recognised, and it was not felt necessary to employ a second reader. In addition, it was identified that 44 patients had other potential causes of medial foot pain; however, only four of these had tibialis posterior insertional tendinosis, which is the only pathology that might result in tenderness specifically located at the navicular tuberosity, so it is not felt that these findings would significant alter the results.

In conclusion, certain MRI findings, including os naviculare oedema, navicular tuberosity oedema, and oedema of the overlying soft tissues, are highly specific to symptomatic os naviculare, being largely absent in asymptomatic cases. Therefore, in the correct clinical setting, it can be concluded that os naviculare is responsible for symptoms in patients presenting with medial foot pain and/or

tenderness over the navicular tubercle who are also found to have the aforementioned MRI findings. On the other hand, due to the low sensitivity of these measures, absence of such MRI findings may not exclude the os naviculare as a pathological source for patients' symptoms.

Conflicts of interest

The authors declare no conflict of interest.

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References

1. Golano P, Fariñas O, Saenz I. The anatomy of the navicular and periarticular structures. *Foot Ankle Clin* 2004;**9**:1–23.
2. Gunal I, Yorukoglu K. Osteonecrosis of the accessory navicular bone. *Arch Orthop Trauma Surg* 2001;**121**:546–7.
3. Miller TT, Staron RB, Feldman F, *et al*. The symptomatic accessory tarsal navicular bone: assessment with MR imaging. *Radiology* 1995;**195**:849–53.
4. Emms NW, Walsh HPJ. Stress fracture of the accessory navicular: a rare cause of foot pain. *Foot Ankle Surg* 2001;**7**:241–3.
5. Romanowski CAJ, Barrington NA. The accessory navicular — an important cause of medial foot pain. *Clin Radiol* 1992;**46**:261–4.
6. Grogan DP, Gasser SI, Ogden JA. The painful accessory navicular: a clinical and histopathological study. *Foot Ankle* 1989;**10**:164–9.
7. Kidner FC. The prehallux (accessory scaphoid) in its relation to flat-foot. *J Bone Jt Surg Am* 1929;**11**:831–7.
8. Mygind HB. The accessory tarsal scaphoid: clinical features and treatment. *Acta Orthop Scand* 1953;**23**:142–51.
9. Lawson JP, Ogden JA, Sella E, *et al*. The painful accessory navicular. *Skeletal Radiol* 1984;**12**:250–62.
10. Kopp FJ, Marcus RE. Clinical outcome of surgical treatment of the symptomatic accessory navicular. *Foot Ankle Int* 2004;**25**:27–30.
11. Ugolini PA, Raikin SM. The accessory navicular. *Foot Ankle Clin* 2004;**9**:165–80.
12. Geist ES. Supernumerary bone of the foot: a roentgen study of the feet of 100 normal individuals. *Am J Orthop Surg* 1914;**12**:403.
13. Sella EJ, Lawson JP, Ogden JA. The accessory navicular synchondrosis. *Clin Orthop Rel Res* 1986;**209**:280–5.
14. Sizensky JA, Marks RM. Imaging of the navicular. *Foot Ankle Clin* 2004;**9**:181–209.
15. Chen YJ, Hsu RWW, Liang SC. Degeneration of the accessory navicular synchondrosis presenting as a rupture of the posterior tibial tendon. *J Bone Jt Surg* 1997;**79-A**:1791–8.
16. Chiu NT, Jou IM, Lee BF, *et al*. Symptomatic and asymptomatic accessory navicular bones: findings of Tc-99m MDP bone scintigraphy. *Clin Radiol* 2000;**55**:353–5.
17. Demeyere N, De Maeseneer M, Oseteux M. Quiz case, symptomatic type II accessory navicular. *Eur J Radiol* 2001;**37**:60–3.
18. Tuthill HL, Finkelstein ER, Sanchez AM, *et al*. Imaging of tarsal navicular disorders: a pictorial review. *Foot Ankle Spec* 2014;**7**(3):211–25.
19. Mosel LD, Kat E, Voyvodic F. Imaging of the symptomatic type II accessory navicular bone. *Australas Radiol* 2004;**48**:267–71.
20. Takahashi M, Sakai T, Sairyo K, *et al*. Magnetic resonance imaging in adolescent symptomatic navicular tuberosity. *J Med Invest* 2014;**61**(1–2):22–7.
21. Choi YS, Lee KT, Kang HS, *et al*. MR imaging findings of painful type II accessory navicular bone: correlation with surgical and pathological studies. *Kor J Radiol* 2004;**5**(4):274–9.