European Journal of Radiology xxx (2009) xxx–xxx

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Abnormal findings in hallucal sesamoids on MR imaging—Associated with different pathologies of the forefoot? An observational study

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ARTICLE INFO

Article history:
Received 16 December 2008
Received in revised form 26 January 2009
Accepted 29 January 2009

Keywords:
Magnetic resonance imaging
Hallucal sesamoids
Bone marrow edema
Forefoot pain

ABSTRACT

Background: To evaluate the prevalence and localization of abnormalities in the hallucal sesamoids detectable by magnetic resonance (MR) imaging in patients with forefoot pain and to determine which pathologies of tarsus, metatarsus and phalanges are associated with these abnormalities.
Materials and methods: The forefoot MRI examinations of 50 consecutive patients (32 females, 18 males; mean age 51 years, age range 20–86 years) were retrospectively analyzed by two musculoskeletal radiologists. A minimum of coronal and sagittal T1-weighted images and STIR images or T2-weighted images with fat saturation were performed on a 1.5-T scanner. Abnormal findings in the sesamoids were correlated with pathology in the I.MTP (metatarsal-phalangeal) joint, pathology in other parts of the forefoot and clinical information.
Results: Signal abnormalities of the sesamoids were found in 7 patients out of 50 (14%). Two patients presented a bone marrow edema (BME) in both sesamoids, in 1 patient only the lateral one was affected; all three associated with pathology and pain in the I.MTP joint. In four patients only the medial sesamoid was affected, not associated with pathology in the I.MTP joint but with pathology in other parts of the forefoot.
Conclusion: The prevalence of signal abnormalities in hallucal sesamoids was 14%. BME of the lateral sesamoid or of both were predominantly associated with pathology in the I.MTP joint. In contrast, signal abnormalities of the medial sesamoid, without affection of the lateral one, were associated with pathology in other parts of the forefoot suggesting an overuse injury as a result of compensating posture.

1. Introduction

Forefoot pain is a very common reason for physician visits. The variety of causes of metatarsalgia and forefoot pain includes, among other pathologies, disorders of the first metatarsal-phalangeal joint (I.MTP) and the hallucal sesamoid complex. Mechanical overuse, stress fractures, osteochondritis, chondromalacia, and avascular necrosis of the hallucal sesamoid bones belong to the same pathologic spectrum, have common etiological factors, and present clinically with a painful syndrome in the I.MTP joint [1–4]. The hallucal sesamoids play an important role in the function of the great toe by absorbing the weight-bearing pressure of the foot, reducing friction, and protecting the tendon of the flexor hallucis brevis. The anatomic location of the hallucal sesamoids and their functional complexity make them vulnerable to injury, which may cause persistent forefoot pain [5]. They are prone to injury in repetitive high-impact and contact sports, long-distance running, and jogging [4,6,7]. About 12% of injuries affecting the I.MTP and the hallucal sesamoid complex are traumatic sesamoid injuries [8], most of which due to overuse [4]. The most common pathological finding in the I.MTP joint and the hallucal sesamoid complex is degenerative osteoarthritis, often in combination with hallux valgus deformity [9]. Sesamoiditis may also occur as a postoperative complication after surgery [10].

Magnetic resonance (MR) imaging is a widely used tool for the diagnosis of abnormalities of the musculoskeletal system. For the investigation of the I.MTP joint and the hallucal

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doi:10.1016/j.ejrad.2009.01.040

sesamoid complex, MR imaging plays an important role in differentiating soft tissue from osseous pathology [1,11]. Early and accurate diagnosis of sesamoid complex disorders can prevent potentially harmful longstanding joint dysfunction [11]. A standard MR imaging protocol for a forefoot examination normally includes the region of the great toe and the hallucal sesamoid complex. Nevertheless, examination of the hallucal sesamoids by MR imaging has not garnered much attention in the literature, although forefoot pain is a very common reason for physician visits.

The aim of this small observational study was to determine the prevalence and localization of signal abnormalities in the hallucal sesamoids, and to determine which pathologies of the tarsus, metatarsus, and phalanges are associated with abnormalities in the I.MTP joint and the hallucal sesamoid complex.

2. Materials and methods

To determine the prevalence and localizations of abnormalities in the hallucal sesamoids, we retrospectively reviewed MR images of 50 consecutive patients (32 females; 18 males; mean age, 51 years; age range, 20–86 years), who had undergone MR imaging of the forefoot between March 2003 and August 2005 at our institution. The project received approval by the local ethics committee. The criteria for inclusion in the study were (a) the presence of persistent forefoot pain (mean duration, 7 months; range, 1–48 months), assessed by either an orthopedic specialist or a general practitioner, and (b) the availability of high quality MR images, characterized by the absence of motion artifacts, efficient fat suppression/saturation, and clear visibility and complete depiction of the hallucal sesamoids on all MRI sequences.

Clinical information, extracted from the letter of referral, was collected for all patients. In addition, patients were asked to report previous sports activities, trauma, or surgical interventions of the foot and to describe the specific localization of pain and the duration of symptoms.

2.1. MR imaging and image analysis

MR imaging of the forefoot was performed using a 1.5-T scanner (Philips Gyroscan Intera 1.5T, Release 11.1, Philips Medical Systems), equipped with a circular polarized head coil. The patients were placed in the supine position, feet first, with both feet in the head coil and a neutral position of the feet, fixed with wedges. MR imaging protocols varied among different patients and clinical questions. However, all MRI examinations included coronal and sagittal T1-weighted images, and coronal and sagittal STIR or T2-weighted images with fat saturation. Repetition time (TR) and echo time (TE) were 400–750/6–9 ms the T1-weighted turbo spin-echo (TSE) images, 1800/70 ms for the T2-weighted images with fat saturation, and 1400/15 ms for the STIR images. For all MRI sequences, a slice thickness of 3–5 mm, an interslice gap of 0.3–0.5 mm, a field of view (FOV) of 160–200 mm^2, and a matrix size of 256 × 256 were used. The images were printed on laser film and the data of the images were saved in PACS (Picture Archiving & Communication System).

The assessment technique was an independent interpretation of the digital images (DICOM format), performed by an experienced musculoskeletal radiologist and a radiologist-in-training in consensus, both aware of clinical information. We analyzed the quantity and quality of signal abnormalities in the hallucal sesamoids, such as a bone marrow edema (BME) pattern or fibrotic tissue, the presence of bone fragmentation, or a severe dislocation in the medial or lateral sesamoid or in both sesamoids. BME in the sesamoids was defined as a diffuse signal alteration of the bone marrow, with high signal intensity on STIR images or T2-weighted images with fat saturation, and low signal intensity on T1-weighted images [1,11], short and long axes. BME was graded as either "moderate" (focal BME pattern), or "severe" (affection of the whole bone). Fibrotic tissue was characterized by bone marrow alterations of low signal intensity on both STIR or T2-weighted images with fat saturation, and T1-weighted images [1,11].

In addition to the evaluation of abnormalities of hallucal sesamoids, type and specific localization of pathological findings of the forefoot, including tarsus, metatarsus and the I.MTP joint, were also assessed.

2.2. Statistical analysis

A Chi-squared test at the 5% significance level was used to determine whether there was an association between lesions of the hallucal sesamoids and the localization of different pathologies in the forefoot.

3. Results

MRI examinations revealed a BME pattern of the hallucal sesamoids in 7 (14%) of the 50 patients (3 men, 4 women; mean age, 62 years; see Table 1). Isolated BME of the medial sesamoid was more frequent (8%) than BME of both sesamoids (4%) and isolated BME of the lateral sesamoid (2%). Fibrotic tissue was not observed in any of the patients.

Pathology in the I.MTP joint was found in 31 patients (62%), with osteoarthritis being the most common finding. Other pathologies

Table 1
Patients with detectable bone marrow edema in hallucal sesamoids.

Patients gender, age	Edema in sesamoids, localization and intensity	Pathology in I. met. phal. joint	Pathological findings of the forefoot, including tarsus and metatarsus	Localization and duration of pain, history of trauma or surgery
Male, 44	Medial, moderate	No pathology	Periostitis Os MT II	Lateral ankle joint, tarsus, MT II/III, pain for 1 month, no trauma
Female, 72	Medial, severe	No pathology	Bone marrow edema in medial sesamoid, osteochondritis of the ankle joint	Plantar MTP joint I–III and ankle joint, pain for 2 months, no trauma
Male, 38	Medial, severe (Fig. 1a and b)	No pathology	Os vesalianum with bone marrow edema phalangeal V	MT and Phalanx V, pain for 1 month, no trauma
Male, 17	Medial, moderate	Effusion, moderate	Bone marrow edema of tarsal bones	Whole tarsus, pain for 2 months, no trauma
Female, 62	Lateral, moderate (Fig. 3a)	Osteonecrosis of head I.MT after surgery (hallux valgus)	Osteonecrosis of head I.MT after surgery (hallux valgus)	I.MTP joint, pain for 11 months since surgical removal of osteosynthesis material
Female, 53	Both, moderate	Osteoarthritis after surgery (hallux valgus)	Osteoarthritis after surgery (hallux valgus)	I.MTP joint, pain for 6 months, 3 years after surgery
Female, 64	Both, moderate (Fig. 2a–c)	Osteoarthritis, dislocation of the sesamoids after surgery (hallux valgus)	Osteoarthritis, dislocation of the sesamoids after surgery (hallux valgus), scarred tissue	I.MTP joint, pain for 8 months since surgery

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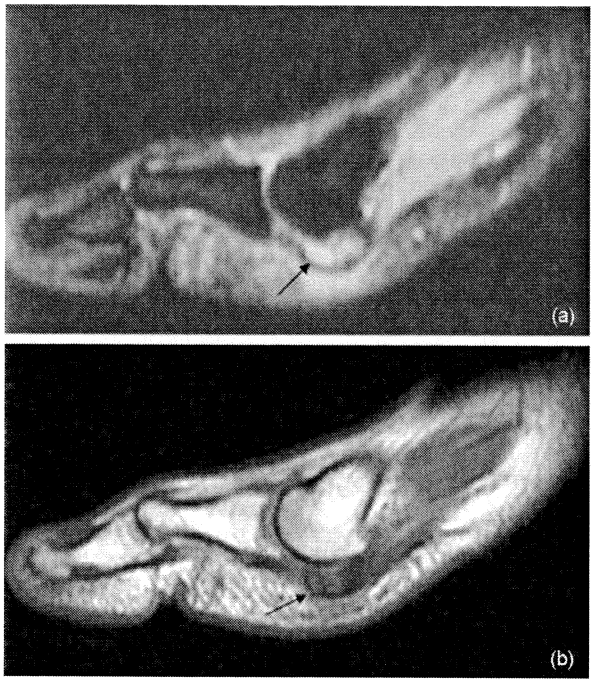

Fig. 1. STIR MR image (a) and T1-weighted image (b) in the sagittal plane of a 38-year-old man with a severe bone marrow edema in the medial sesamoid (arrows).

found in the forefoot region are listed in Table 2. In six patients, no morphological or radiological correlation for the symptoms could be detected.

Stratifying patients according to their forefoot pathologies ((a) pathological findings in the I.MTP joint; or (b) pathological findings located in other parts of the forefoot), the Chi-squared test showed that signal abnormalities of the lateral sesamoid or both sesamoids are predominantly associated with severe pathology in the I.MTP joint, whereas signal abnormalities of the medial sesamoid were associated with pathology in other parts of the forefoot ($p = 0.0005$).

4. Discussion

In our observational study, signal abnormalities of the sesamoids that demonstrate pathology were found in a small group of 7 of out of 50 patients. Two patients demonstrated a bone marrow edema pattern in both sesamoids; in one patient only the lat-

Table 2
Pathologies found in forefoot examinations.

Kind of pathology	Number
Osteoarthritis of the I.MTP	12
BME in tarsal and MT bones after trauma	5
Stress fracture of MT III	3
Osteonecrosis of the head of a metatarsal bone	6
Periostitis of MT bones	2
Inflammation of soft tissue of the MT I	5
Foreign body and inflammation of soft tissue of MT III–V	2
Osteomyelitis of the MT and cuneiform bones	1
Osteoarthritis in tarsus and metatarsus	1
Os vesalianum with BME	1
Morton neuroma of MT III/IV	1
Rupture of flexor hallucis longus tendon	1
BME in medial sesamoid with no signs of osteoarthritis	1
Gout-arthritis of the I.MTP joint	1
Scarred tissue after surgical intervention	1
Reflex sympathetic dystrophy	1

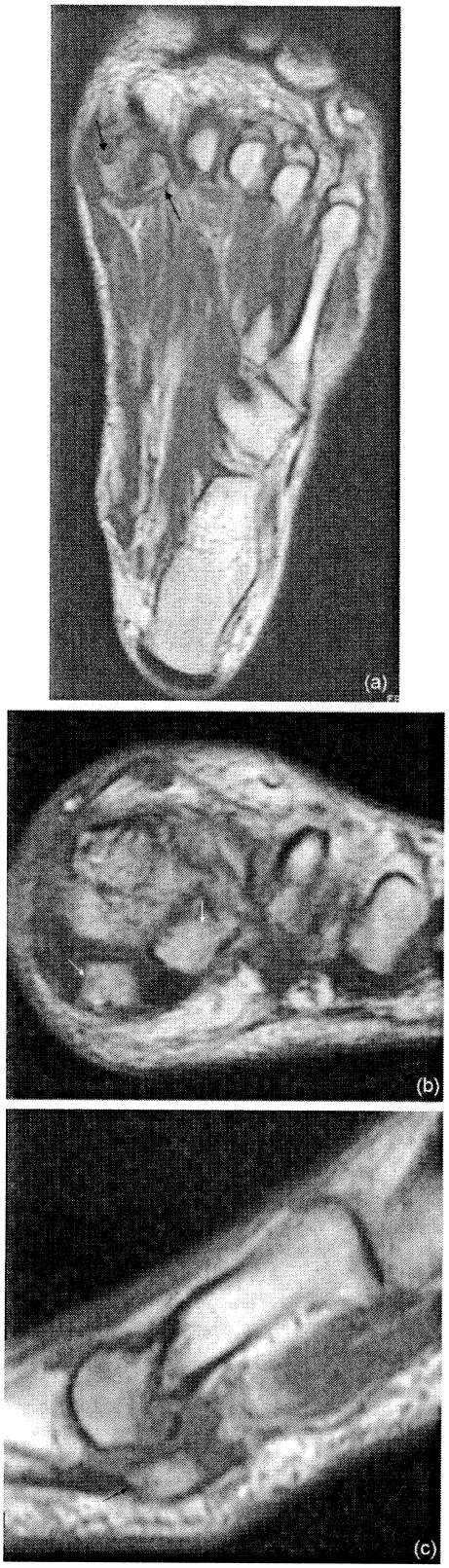

Fig. 2. T1-weighted, fast spin-echo MR image in the axial (a), coronal (b) and sagittal (c) plane of a 53-year-old woman with osteoarthritis of the I.MTP joint and a moderate bone marrow edema in both sesamoids (arrows) after surgery because of hallux valgus.

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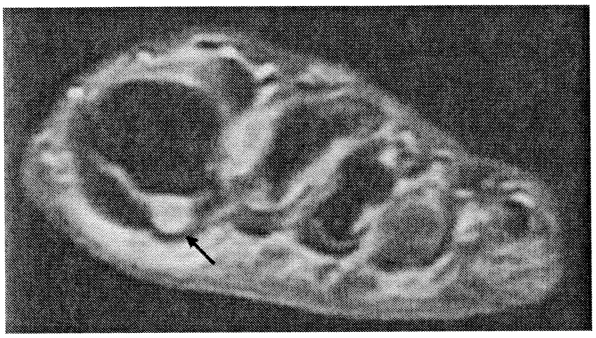

Fig. 3. (a) T2-weighted MR image in the coronal plane of a 62-year-old woman with a moderate bone marrow edema (arrows) in the lateral sesamoid. Main pathology was an osteonecrosis of the head I.MT after surgery because of hallux valgus.

eral sesamoid was affected, and in four patients, only the medial sesamoid was affected. As a new finding, our analysis showed that signal abnormalities of the lateral sesamoid or of both sesamoids are predominantly associated with severe pathology in the I.MTP joint. In contrast, signal abnormalities of the medial sesamoid, without the involvement of lateral sesamoid, were associated with pathology in other parts of the forefoot, suggesting an overuse injury as a result of compensating posture.

Hockenbury and Jahss reported that most injuries of the sesamoids occur due to overuse, caused by activities like jogging and long-distance running, and repetitive high-impact and contact sports [4,6]. However, none of our patients performed these types of activities. In three women, a stress fracture was diagnosed by MRI. However, in both women with stress fractures of the MT III, no BME of the sesamoids could be detected. Seven patients had a history of trauma, but again, no pathologic signal alterations were detected in the sesamoids of these patients. Thus, it seems unlikely that trauma and overuse are a major cause of sesamoiditis.

In the literature, disorders of the hallucal sesamoids are commonly associated with pathological findings in the I.MTP joint. The most common pathological finding in a mixed collective is degenerative osteoarthritis, often with articular erosions that include the whole biomechanical complex and hallux valgus deformity with subluxation of the sesamoids [12,13]. Displacement of the sesamoids may lead to chronic stress and bone marrow edema in the sesamoids. We detected severe pathological findings in the I.MTP joint in 31 of our 50 patients. Three of these patients showed signal abnormalities in the lateral sesamoid or in both, combined with severe pathology in the I.MTP, such as osteoarthritis, osteonecrosis of the I. MT head, and lateral subluxation of the sesamoids. All of them had undergone surgery for hallux valgus deformity before MR imaging and the pain was localized only in the I.MTP joint. The mean age (60 years) of these patients was relatively high.

These findings are well in accordance with the literature, as postoperative complications after surgical intervention for hallux valgus deformity are known to cause sesamoiditis: postoperative complication rates range from 1.1% to 8%, depending on the method of surgical treatment. Complications like superficial and deep wound infections, hypoesthesia, reflex sympathetic dystrophy, nonunion, osteonecrosis of the I. MT head, and complex regional pain syndrome are possible [10,14,15]. Rink-Brune reported that in 16% of patients resolution of swelling and subjective complaints took longer than 3 months; 4.7% of patients developed sesamoiditis or metatarsalgia [10]. Kristen et al. retrospectively evaluated the healing time after SCARF osteotomy, and reported that satisfactory healing time was expressed by an average return back to work of 5.8 weeks and back to sport of 8.3 weeks [14]. In two of the three patients with edema in the lateral sesamoid or in both sesamoids, pain occurred immediately after surgery. After duration of persistent pain of 8 and 11 months, these patients were referred to our institution for MRI. Persistent pain and MRI findings were associated with postoperative complications, such as osteonecrosis of the I.MT head, dislocation of the sesamoids, and sesamoiditis. In the third patient, pain occurred 3 years after surgery for hallux valgus; this patient had no postoperative complications and no persistent pain after surgery, but developed degenerative osteoarthritis in the I.MTP where the pain was felt.

In four patients, we detected signal abnormalities only of the medial sesamoid. Surprisingly, none of these patients showed pathology in the I.MTP joint, except for a moderate effusion in one patient. Also, none of these patients had hallux valgus deformity, direct trauma of the hallucal sesamoid complex, or surgery of the forefoot in their clinical history; any sports activities in their history which may have caused a primarily overuse injury to the sesamoids was excluded by the questionnaire. All of these patients had localized pain in the tarsus and metatarsus, only one of them had additional pain in the I./II.MTP, with duration of pain from 1 to 2 months (Table 1). Rather, we found pathology of the tarsus and metatarsus, such as periostitis of the MT II, Os vesalianum, and tarsal bones with bone marrow edema.

In accordance, Ashmann et al. described an "amorphous area of decreased signal intensity within the marrow on T1-weighted MR images that increases in signal intensity on corresponding T2-weighted and STIR images," similar to the signal abnormalities we found in the sesamoids. This finding was called a "stress response," which is a "non-specific finding, and correlation with clinical findings is essential for making a correct diagnosis" [1]. Hockenbury et al. claim that most injuries of the sesamoids are overuse injuries, although direct trauma or forced dorsiflexion of the hallux may lead to acute fracture of the sesamoids.

The hallucal sesamoids bear up to almost three times the body weight during a normal gait cycle, the majority of which is borne by the medial sesamoid [4]. Patients with pathology and pain in the tarsus, metatarsus, and the phalangeal region II–V tend to shift weight to the far medial part of the forefoot to relieve the painful region. The edema of the medial sesamoid seems to be another kind of overuse injury, caused by chronic stress. A stress reaction, predominantly in the medial sesamoid, which absorbs most of the weight-bearing pressure, can be the result and can lead to severe disorders of the hallucal sesamoid complex.

Pathological reactions in the sesamoids because of overuse and chronic stress might easily be overlooked in patients who do not have localized pain in the I.MTP joint but in the region of the tarsus and metatarsus.

Hallucal sesamoid bone disorders can be difficult to diagnose. To detect fragmentation and anatomic variants of the sesamoids, the AP radiograph, and, in some cases, a CT scan, is the standard method of diagnosis. Bone scintigraphy has also been frequently used to evaluate suspected hallucal sesamoid pathology. Increased scintigraphic activity of the hallucal sesamoid was assumed to corroborate with clinical suspicion of pathology [16].

MR imaging is an excellent and sensitive method to detect signal abnormalities, even in small bones like the hallucal sesamoids that demonstrate a bone marrow edema or fibrous tissue replacing the fat. In most cases of pathology in the sesamoids, including sesamoid osteoarthritis, avascular necrosis, and fracture and mechanical overuse, a signal abnormality becomes visible during the first few days by a focal or diffuse high signal intensity of the bone marrow detectable by MRI. MRI is particularly helpful in the early stages of disease in confirming these diagnoses, as presented in several case reports [7,17,18].

However, our MR imaging technique has a limiting factor: in cases of subluxation of the hallucal sesamoids, we were not able to quantify exactly the rotational position.

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In one patient with degenerative osteoarthritis after surgical intervention because of hallux valgus deformity, we found displacement and a bone marrow edema in both hallucal sesamoids. Lateral displacement of the hallucal sesamoids frequently occurs with the development of hallux valgus deformity [18], and, in case of surgical intervention, the restoration of a congruent metatarsal-sesamoid joint has been proposed as essential for an optimal operative result [19]. Several methods have been published to quantify subluxation of the sesamoids [19,20], and a weight-bearing tangential radiograph has been established as the best view. Schweitzer et al. used the long axis of the first metatarsal as a reference to evaluate the amount of displacement and the severity of valgus deformity in an MRI study of hallux valgus and hallux rigidus [18]. Weishaupt et al. suggested that a weight-bearing MRI of the forefoot may be useful in preoperative planning and postoperative evaluation of metatarsal osteotomies, and for correlation of positional dependent changes of anatomical structures of the forefoot with patients' pain [2]. However, in cases of preoperative radiologic diagnosis of a hallux valgus deformity, a special weight-bearing tangential radiograph is still considered the standard diagnostic method [20].

5. Conclusion

The results of our observational study suggest that pathological findings in both sesamoids, especially in the lateral one, are predominantly associated with severe pathology in the I.MTP joint. Degenerative processes like osteoarthritis of the I.MTP joint involving the hallucal sesamoid complex, hallux valgus deformity with displacement of the sesamoids, and postoperative complications after surgery are predicting factors. When a signal abnormality in the medial sesamoid is detected, with no pathological findings in the I.MTP joint and without subluxation of the sesamoids, the whole foot, including the tarsus, should be investigated to search for pathological findings that may cause compensating posture and follow chronic stress of the sesamoid.

We suggest investigating the hallucal sesamoid complex carefully in every MR imaging examination of the forefoot. Further studies with a larger study population are needed to validate our results.

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