CHAPTER 9

Bone marrow hyperintensities with tarsal coalition: MR imaging findings

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Abstract

Objective. To report the occurrence and pattern of ill-defined subchondral hyperintensities on MR (MR) imaging in patients with talocalcaneal coalition (TCC).

Method and material. MR imaging of both feet was performed in 10 consecutive patients with 14 TCCs. There were 8 males and 2 females with ages ranging from 9-52 years (mean 25 years). Twelve of the 14 TCCs were symptomatic. MR imaging sequences included T1- and T2-weighted as well as short tau inversion time inversion-recovery (STIR) images. The images were evaluated for the presence, extent and location of ill-defined subchondral hyperintensities on MR in the hindfoot.

Results. Ill-defined subchondral hyperintensities on MR imaging were present in 12 (86%) of the 14 hindfeet with TCCs. Two of these were without symptoms. No abnormalities were seen in two symptomatic hindfeet.

Discussion and conclusion. In our series hyperintensities located in the subchondral bone adjacent to the coalition were relatively common in TCC. The presence of this specific pattern in the subchondral bone adjacent to the coalition may be indicative of tarsal coalition.

Introduction

A tarsal coalition refers to abnormal fusion of two or more independent bones of the hindfoot [1]. The most common coalitions are those between the talus and calcaneus, and between calcaneus and the navicular bone. Of these, the talocalcaneal coalition (TCC), as a weightbearing joint, is clinically the most important because it frequently causes symptoms, such as pain and giving way (instability), starting when the coalition ossifies and the foot becomes rigid [1]. In most instances, the symptoms begin at puberty sometimes following a traumatic event or repetitive injury [1-4].

With conventional radiography secondary signs of the hindfoot such as degenerative changes, talar beaking and narrowing of the posterior subtalar joint may suggest a coalition, resulting from longstanding abnormal subtalar movement. These changes, indicating hindfoot abnormality, have also been demonstrated with radionuclide studies using bone-seeking radiopharmaceuticals, although the findings have been rather non-specific [3].

It may be difficult to demonstrate the TCC by conventional x-ray radiography because visualization of the middle facet of the posterior subtalar joint is frequently hampered by
superposition of the tarsal bones and by the oblique orientation of the coalition. Demonstration may also be difficult when the coalition is non-osseous, consisting of fibrocartilagenous tissue, or when there is incomplete skeletal maturation [5].

CT has been demonstrated to be useful in depicting the site of the talocalcaneal fusion, but has limitations in visualizing fibrous coalitions [2,4,6].

MR imaging is a noninvasive procedure, which has been shown to depict the bony structures in great detail, including those of the hindfoot [6]. It has also been demonstrated that coalitions are better depicted with MR imaging than with CT, particularly the fibrous types [2,6]. An additional advantage of MR imaging is that the bone marrow is well-visualized [2]. Studies have shown that reactive changes such as arthritis or edema from stress, involving the marrow, are readily depicted with MR imaging [7].

Treatment usually consists of conservative measures. Resection of the coalition is advocated when conservative therapy fails and symptoms persist [8]. Preferably, surgery is performed early when the lesion still consists of cartilaginous tissue or immature bone. Early treatment allows improved remodeling of the adjacent foot bones and more effective improvement of the subtalar mobility, thereby preventing the development of (further) osteoarthritis [9].

The purpose of our study was to determine prevalence and extent of a hyperintensity pattern in the hindfoot in patients with TCC as demonstrated by MR imaging.

Materials and methods

We retrospectively reviewed the MR images of all consecutive patients who had undergone MR imaging of the hindfoot at our institution for pain and instability, between January 1996 and December 1998. In all patients symptoms persisted for at least three months. Often the patients could relate the onset of the symptoms to a (minor) trauma. The clinical symptoms consisted of pain in the hindfoot aggravated by exercise, limited or absent subtalar motion, flatfoot and peroneal spasm [4,7]. MR images were reviewed by two reviewers in consensus for the presence of hyperintensities on T2-weighted and short tau inversion time inversion-recovery (STIR) images, around the middle facet of the subtalar joint. The reviews were done without knowledge of the clinical findings and the results of the radiographs. Only when there was an area of abnormal marrow signal intensity (SI) located in the adjacent subcortical regions of talus and calcaneus, consisting of increased SI on T2-weighted and STIR images, it was considered as an abnormal bone marrow pattern.
The MR images were reviewed with special attention to bony abnormalities suggestive of a TCC. A coalition was considered to be ‘osseous’ when there was continuity of bone marrow across the mid-subtalar joint. The coalition was considered ‘non-osseous’ when there was subtle, irregular narrowing or an abnormal slope of the middle facet joint, with the SI of cartilage or joint fluid depicted between the suspected bones, or an area of intermediate to low SI bridging the adjacent bones within an aberrant articulation [2]. The presence of abnormal subchondral bone marrow pattern in the symptomatic feet was compared with the presence of subchondral bone marrow pattern in the asymptomatic feet using an unpaired t-test with a level of significance P < 0.05.

MR imaging was performed using a 0.5 Tesla system (Philips, Best, the Netherlands) with both hindfeet placed in a dedicated receive-only extremity coil. In each patient, the feet were imaged together. Conventional T1-weighted SE (repetition time (TR)/echo time (TE) 600 ms/23 ms) and T2-weighted SE (TR/TE 2000 ms/100 ms) images were obtained in axial and coronal orientation. STIR (3600 ms/20 ms; inversion time (TI) = 150 ms) images were obtained in coronal and/or sagittal planes. Slice thickness varied between 3 and 5 mm; the interslice gap varied between 0 and 1.5 mm. The matrix size was 256 x 256 and the field-of-view was 16 cm.

CT was performed in 7 patients, with a high-resolution technique on a helical CT scanner (Tomoscan SR 7000, Philips Medical Systems, Best, the Netherlands). Angled coronal contiguous slices (thickness 3 mm) above the talocrural joint to the calcaneocuboid joint, using a bone algorithm, were obtained. The CT criterium for osseous TCCs was a complete osseous bar between the mid-subtalar joint. Non-osseous TCCs were described as articular narrowing and cystic cortical irregularity, subchondral sclerosis, or abnormal slope of the joint.

All patients had a conventional x-ray examination of the hindfoot in anteroposterior, lateral and oblique projections.

After each MR review the reviewers analyzed the hindfoot radiographs or CT examination, if available, of each case with knowledge of the MR imaging findings.

Results

A TCC was present in 14 hindfeet of 10 patients. Of the 343 consecutive MR examinations of the hindfoot performed for persisting symptoms of pain or stiffness in the foot, ill-defined hyperintensities on both sides of the talocalcaneal joint were found in 12 feet, involving 10 patients (table 1). The duration of the symptoms in this group of 10 patients
ranged between 3 and 26 months (mean, 16 months) before MR imaging was performed. There were 8 males and 2 females with ages ranging between 9 and 52 years (mean 25 years). TCCs were present in 12 symptomatic feet and two additional TCCs were found in two asymptomatic feet.

In 5 patients the coalition was confirmed by surgery. In another 7 patients CT confirmation was made. In two coalitions only MR examination was performed.

Non-osseous union was suggested by x-ray radiography in 7 of the 14 coalitions by subtle irregularity and narrowing or abnormal slope of the middle facet joint, narrowing of the posterior subtalar joint, talar beaking or overgrowth or undergrowth of the sustentaculum tali and medial process of the talus. Incomplete skeletal maturation existed in 2 patients, but the coalition was suggested in one patient by secondary signs of the hindfoot: irregularity and narrowing of the middle facet joint.

Only one of the coalitions was osseous, and all other ones were non-osseous. Six TCCs were present in the right and eight in the left foot. In 9 of the 14 hindfeet there was focal increased SI involving the bone marrow of both the talus and calcaneus directly adjacent to the coalition (Fig. 1 and 2). None of the 329 asymptomatic feet showed the typical ill-defined bone marrow pattern. In the two children the specific "heterogeneous bone marrow signal" involved the talus and calcaneus adjacent to the coalition (one bilateral and one unilateral coalition), together with foci of high SI also noted to be present in the remainder of talus and calcaneus on the symptomatic and contralateral, asymptomatic side (Fig. 3). No hyperintensities were found in two of the 14 hindfeet, with one of those involving an osseous TCC. There was a significant difference in the symptomatic and asymptomatic group (P < 0.05), as regards to the presence of typical bone marrow pattern.

Table 1. Talocalcaneal coalition.

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<th>Hyperintensities*</th>
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<td>Symptomatic</td>
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<td>Asymptomatic</td>
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* On T2-weighted and short inversion time inversion recovery (STIR) images, around middle facet of subtalar joint.
Figure 1.
A. Anteroposterior radiograph of the hindfoot of a 20-year-old man with unilateral pain and instability, showing coalition (arrow) of the middle facet of the subtalar joint.
B. Coronal T2-weighted SE (TR/TE 2000 ms/100 ms) MR image of the left hindfoot showing fibrous coalition (arrows) with an enlarged sustentaculum and medial process of the talus and abnormal slope of the middle facet joint. The contralateral middle facet joint is normal.
C. Coronal short tau inversion recovery (STIR, repetition time/echo time/inversion time 3600 ms/20 ms/150 ms) demonstrates ill-defined hyperintensities (arrows) in the subchondral bones adjacent to the coalition.
Discussion

Tarsal coalitions are believed to be congenital in origin and caused by failure to segment the tarsal bones resulting in absence of normal joint formation. The most common types are those between the talus and calcaneus and between calcaneus and navicular bone; however other bones of the foot can also be involved [9]. Tarsal coalitions are often bilateral (50%). Simultaneous evaluation of the opposite foot is therefore recommended [4]. Men are more commonly affected than women [2]. Early diagnosis is important because the coalition may lead to joint problems and disability of the foot, particularly when activities are performed that are stressful for the foot.

The first symptoms usually appear between the ages of 12 and 16, when the coalition ossifies, causing increased rigidity of the foot [1,7]. However, limitation of the subtalar motion may sometimes be difficult to diagnose in the presence of a coalition. Pain is usually not the result of the fusion itself, but is caused by disturbances in the inversion/eversion motion of the hindfoot [3,9,10]. In adult patients it may be caused by arthritis rather than muscle spasm [8].

Figure 2.
A, Coronal CT scan of a 28-year-old man with unilateral painful hindfoot, showing a fibrous coalition as evidenced by an irregular narrow middle facet joint (arrows).
B, Sagittal T1-weighted SE (TR/TE 600 ms/23 ms) MR image shows fibrous coalition with an abnormally narrowed and irregular middle facet joint (arrow).
C, Coronal short tau inversion recovery (STIR, repetition time/echo time/inversion time 3600 ms/20 ms/150 ms) demonstrated the presence of ill-defined hyperintensities adjacent to the middle facet of the subtalar joint (arrows).
We found 14 (4%) TCCs in 343 patients, this is well within the range 1-6 % reported in the literature [1]. In twelve patients (86%) the hyperintensity pattern was present in the subchondral bone marrow adjacent to the coalition. This bone marrow pattern was absent in two of the symptomatic coalitions (one of them involving an osseous coalition), while there was hyperintensity around the subtalar joint in two of the asymptomatic patients with TCCs.

It remains unclear what the exact cause of the hyperintensity pattern is in patients with TCC. It is possible that, due to the rigidity of the joint involved by the lesion, the gliding motion of the joint is hampered, causing abnormal stress on the articular surfaces and the subchondral bone of the joints adjacent to the fusion. As a result, “stress may exceed
bone strength” resulting in microfractures of the subchondral trabecular bone, causing edema. It has also been postulated that the augmented concentration of radionuclides in scintigraphy is most likely the result of abnormal forces on the bone adjacent to the subtalar coalition and not at the side of the fusion itself where there is no motion or bone turnover [3]. Predominance of the hyperintensity in the tarsal bones appears to correlate with the distribution of stress fractures [2]. Reactive changes as focal marrow fibrosis, fibrovascular granulation tissue replacing fatty marrow, or early avascular necrosis at the subchondral location secondary to degenerative articular disease, must also be considered, especially in the adult patient [13].

In the two children of our series with symptomatic coalitions, hyperintensities were seen adjacent to the coalitions, together with foci of high SI involving the entire talus and calcaneus of both feet. A similar pattern has been described in a series of children without coalition [12]. A symmetric, heterogeneous edema pattern was found in 57% of those children (N = 35) aging between 6 and 15 years, who had no evidence of coalitions or other pathologic findings, leading to the conclusion that these patterns of edema in the hindfoot represented a normal finding in the growing skeleton [12].

To our knowledge, the presence of a hyperintensity pattern in patients with coalition has not been described in earlier series involving patients who underwent MR imaging. One case report noticed “bone marrow edema” in the calcaneus, talus and cuneiform in a 41 year old woman with a TCC [8]. However, in most reports dedicated MR pulse sequences such as STIR were not used to provide good image contrast between fat and water [5]. The use of such sequences has been shown to be important in demonstrating bone marrow hyperintensities [7].

Our study does have several limitations. First, it involved only a small number of patients. However, coalitions of the hindfoot are relatively uncommon. Second, surgical proof of the coalition was only obtained in five patients who underwent exploration or arthroscopy of the foot. However, the presence of a coalition was also confirmed in all of the patients based on the findings of CT and radiography. Third, the finding of bone marrow ill-defined high-signal-intensity zones on STIR or T2-weighted images is nonspecific and other diagnoses also need to be considered [13]. These include stress response, transient osteoporosis or reactive changes secondary to degenerative articular disease.

In conclusion, on MR imaging T2-weighted and short tau inversion-recovery (STIR) images we found a high occurrence of (ill-defined) hyperintensities (86%) in patients with a coalition of the hindfoot. In most cases, the findings were focal and involved the subchondral bones adjacent to the TCC. In our opinion the presence of this typical bone marrow
pattern in the middle facet joint between talus and the calcaneus is suggestive for tarsal coalition. So when ill-defined hyperintensities are found in the talus and calcaneus adjacent to the middle facet in a patient undergoing MR imaging of the foot, the presence of a coalition needs to be considered.

References