INTRODUCTION

The accessory navicular bone, which is also termed “os tibiale externum”, is one of the most common accessory ossicles, with a reported incidence of 10-26% (1-3). As most accessory navicular bones are asymptomatic, they are often erroneously considered as normal anatomic and roentgenographic variants. However, they can become symptomatic when trauma affects the synchondrosis of the accessory navicular. The symptomatic condition is mainly associated with type II accessory navicular bone, in which there is a large, triangular ossification center adjacent to the navicular tuberosity that is connected by a synchondrosis measuring 1-3 mm (4, 5). This type of accessory navicular bone can be easily distinguished from type I accessory navicular bone which is a sesamoid imbedded in the tibialis posterior tendon and separated from the navicular tuberosity by at least 3 mm (5-7). The cause of symptom is thought to be repetitive tension and shear stress across the synchondrosis as a result of the pull of the posterior tibial tendon (8).

Recently, it has been reported that magnetic...
resonance (MR) images of symptomatic type II (spondychrosis type) accessory navicular bone showed an “edema-like bone marrow pattern” (9-11). Edema-like MR abnormality was also reported in the posterior tibial tendon in adults with flatfoot (12, 13). However, these MR abnormalities have been described mostly in the symptomatic adults, but not in the adolescents with symptomatic navicular tuberosity, nor in correlation with the alleviation of symptom or the presence of accessory navicular. Therefore, the purpose of this study was to evaluate the prevalence of edema-like bone marrow pattern of adolescent symptomatic navicular tuberosity in correlation with the course of symptom and the presence of accessory navicular bone. We hypothesized that edema-like bone marrow pattern could tell the symptom of navicular tuberosity and the intensity of the pattern could tell the intensity of symptom.

MATERIALS AND METHODS

The investigation was performed in accordance with the institutional review board and ethics committee of the University of Tokushima. The subjects of this investigation were ten consecutive adolescent patients (5 males and 5 females) with a mean age of 11.5 years (range 9 to 14 years) presenting with pain localized to the navicular tuberosity (Table 1). Two patients complained of bilateral symptoms and the others had unilateral symptom (5 on the right and 3 on the left); all symptoms were aggravated by physical activity. No patients complained of pain or tenderness on another part of the foot. Either acute injury or chronic overuse preceded the onset of symptoms in all cases with continuous participation in athletic activities. The average duration of symptom before presentation was – 1.8 months. Physical examination revealed that all except one patient (case 6, see Table 1) had flexible flatfoot. Static footprints were recorded on a Harris-Beath mat in the half body weight-bearing position (14). The arch index described by Staheli et al. (15) was used to confirm the presence of flexible flatfoot. The symptom was managed non-operatively with suspension of athletic activities in all cases and by wearing a medial longitudinal arch support in all patients with flexible flatfoot until relief of symptom. In more advanced cases, non-steroidal anti-inflammatory medications were used. The symptom was successfully healed in all cases and no patients required surgical intervention to alleviate symptom. The mean period until alleviation of symptom was 3.7 months (range 1.0 to 8.0 months, Table 1).

All patients underwent bilateral radiographic assessments at the initial presentation to determine the type of accessory navicular bone, followed by MR examination within two weeks after the initial presentation. MR examinations were performed on a Signa Profile 0.2-T whole-body MR imaging system (GE Medical System, Milwaukee, WI) using a standard extremity coil. Pulse sequences comprised spin-echo (SE) T1-weighted (repetition time/echo time (TR/TE), 400-500/16-20, 4.0 mm slice thickness; 22 cm field of view, 256 × 256 matrix) and SE T2-weighted fat saturated (TR/effective TE, 4,200-4,500/30-38, 4.0 mm slice thickness; 16-22 cm field of view, 256 × 256 matrix) images obtained in the horizontal and axial planes. MR abnormality was

Table 1. Clinical manifestations of the cases in this study

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (years)</th>
<th>Gender</th>
<th>Symptomatic side</th>
<th>Type of accessory navicular</th>
<th>Presence of flatfoot</th>
<th>Symptomatic athletic activity</th>
<th>Duration of symptom (months)</th>
<th>Period for alleviation (months)</th>
<th>Abnormality at initial MR examination</th>
<th>Number of MR studies</th>
<th>Diminution of MR abnormality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>F</td>
<td>Right</td>
<td>II</td>
<td>+</td>
<td>Athletics</td>
<td>1.5</td>
<td>3.5</td>
<td>+</td>
<td>1</td>
<td>ND</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>F</td>
<td>Bilateral</td>
<td>II</td>
<td>+</td>
<td>Swimming</td>
<td>2.0</td>
<td>4.0</td>
<td>+</td>
<td>2</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>M</td>
<td>Left</td>
<td>II</td>
<td>+</td>
<td>Baseball</td>
<td>2.0</td>
<td>4.5</td>
<td>+</td>
<td>3</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>M</td>
<td>Right</td>
<td>-</td>
<td>+</td>
<td>Tennis</td>
<td>4.0</td>
<td>8.0</td>
<td>+</td>
<td>3</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>M</td>
<td>Left</td>
<td>-</td>
<td>+</td>
<td>Soccer</td>
<td>2.0</td>
<td>4.0</td>
<td>+</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>M</td>
<td>Right</td>
<td>II</td>
<td>-</td>
<td>Basketball</td>
<td>1.2</td>
<td>1.0</td>
<td>+</td>
<td>1</td>
<td>ND</td>
</tr>
<tr>
<td>7</td>
<td>11</td>
<td>F</td>
<td>Right</td>
<td>II</td>
<td>+</td>
<td>Baseball</td>
<td>1.0</td>
<td>3.5</td>
<td>+</td>
<td>1</td>
<td>ND</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
<td>M</td>
<td>Right</td>
<td>-</td>
<td>+</td>
<td>Soccer</td>
<td>3.0</td>
<td>4.0</td>
<td>+</td>
<td>3</td>
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<tr>
<td>9</td>
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<td>10</td>
<td>9</td>
<td>F</td>
<td>Left</td>
<td>II</td>
<td>+</td>
<td>Baseball</td>
<td>1.0</td>
<td>2.0</td>
<td>+</td>
<td>2</td>
<td>+</td>
</tr>
</tbody>
</table>

1; Female (F) or male (M), 2; type of accessory navicular if present and (-) is used in case of absence, ND; not determined, +; present, -; absent.
“edema-like bone marrow pattern”, which was depicted as an area of low signal intensity on T1-weighted images with high signal intensity on T2-weighted fat-saturated images (9, 16, 17). Neither conventional T2-weighted image nor contrast enhancement using an infusion of gadolinium was applied in this study. Seven patients (cases 2, 3, 4, 5, 8, 9 and 10) were willing to be further examined with consecutive MR imaging until heal of the symptom (an average of 2.7 times per patient in this group). We investigated the relationships of the symptom alleviation with type of accessory navicular bone on radiograph and edema-like bone marrow pattern on MRI.

RESULTS

On radiographic examination, accessory navicular bones were found in 7 cases, all of which were bilateral and were classified into type II. In the remaining three patients (cases 4, 5 and 8), no accessory navicular bones were detected on either side. No tarsal coalition or other abnormality was detected.

All symptomatic naviculars presented an edema-like bone marrow pattern (Fig. 1-3) irrespective of whether an accessory navicular bone was present or not. In those patients who took bilateral feet MR examinations, this pattern was observed only on the symptomatic side (Fig. 1). For the seven patients with consecutive MR examinations, the intensity of edema-like bone marrow pattern diminished with alleviation of symptom (Fig. 2 and 3). Surprisingly in the 3 patients without accessory navicular on either side (cases 4, 5 and 8), the navicular tuberosity only presented edema-like bone marrow pattern on the symptomatic side (Fig. 3). This pattern again diminished with the alleviation of symptom. There were no MR abnormalities of the insertion of the posterior tibial tendon, such as signal change of the tendon substance and surrounding fluid throughout this study. We were unable to find any correlation between presence of flatfeet and specific MR findings.

Fig. 1. Bilateral type II accessory navicular bones in case 1. Anteroposterior radiograph (A) of the symptomatic (right) side shows a type II accessory navicular bone (arrow). The ipsilateral T1-weighted (B) and T2-weighted fat saturated (C) horizontal MR images demonstrate edema-like bone marrow pattern on the both the accessory navicular bone and the navicular tuberosity facing to the synchondrosis (arrows), which might be described as “kissing edema pattern”. In contrast, despite the presence of accessory navicular bone (D), asymptomatic navicular bone (in the left foot) does not show edema-like bone marrow pattern on either T1-weighted (E) or T2-weighted fat saturated (F) MR image (arrows).

Fig. 2. For case 3, type II accessory navicular bone on radiograph (A). T2-weighted fat saturated MR image demonstrates the same pattern as the case 1 at the first examination (B). The edema-like bone marrow pattern gradually diminishes with alleviation of the symptom a month (C) and three months (D) after the first presentation.
DISCUSSION

Symptomatic accessory navicular bones are very common conditions and have been reported to occur commonly in adolescence (18, 19). The results of this study indicate that symptomatic navicular in adolescence is described by an edema-like bone marrow pattern on MR image regardless of whether an accessory navicular is present or not, and that alleviation of the symptom is proportional to the diminishment of the edema-like bone marrow pattern. The edema-like bone marrow pattern has been typically shown for symptomatic type II accessory navicular bones, in which the both sides of the synchondrosis present this pattern (9-11). In the present study, there were three patients who did not have accessory navicular bones (cases 4, 5 and 8) but still showed an edema-like bone marrow pattern on the navicular tuberosity. Wong et al. suggested the other pathologic mechanism for symptomatic navicular tuberosity in their study of 18 adolescents who had flexible flatfoot with pain of the navicular tuberosity and completed MR examination (20). They concluded that the symptom was not confined to the accessory navicular synchondrosis, and that an enthesopathy like process occurred at the insertion of posterior tibial tendon to the navicular in some cases (20). In the present study, three patients who did not have accessory navicular bone obviously showed bone marrow abnormality, although no patients showed MR abnormality of posterior tibial tendon. In addition to the mechanisms described by Wong et al., we speculate another pathologic mechanism in adolescents, such as an osteitis or osteochondrosis. Thus, we have to manage carefully the adolescent patients with symptomatic navicular tuberosity even without an accessory bone.

The edema-like bone marrow pattern in the navicular tuberosity diminished with the alleviation of symptom managed non-operatively in this study. The intensity of edema-like bone marrow pattern, especially the signal intensity on T2-weighted fat saturated images, may indicate pain intensity, despite the small number of patients in the current study and no quantifications of the intensity. To our knowledge, among previous studies of symptomatic foot conditions, only one tried to demonstrate a relationship between MR parameters and pain (16). There was, however, no correlation between bone marrow edema volume and peak pain intensity among patients with various ages. They did not investigate any relationships between bone marrow edema intensity and peak pain intensity.

Our study might have several limitations related to study design. First, the sample number was small and any statistical analyses were not performed in this study. Second, we did not have surgical or histologic correction of samples. The edema-like bone marrow pattern have been reported to reflect several different pathologic conditions except for true edema, such as bone marrow necrosis and fibrosis (21), fibrovascular tissue ingrowth and increased blood flow to the area (22), and reactive new bone formation (9). The background of conditions such as age of the patient, the cause of trauma, and anatomic location should be taken into account. Because we did not examine sagittal MR images in this study,
it is possible that we failed to detect pathologic conditions of the posterior tibial tendon, which were presented in previous studies (10, 20). Bone marrow signal changes were definitely detected on both the horizontal and axial MR images of all the symptomatic navicular in our study. Finally, the low-magnetic field MR used in this study might influence the results. There were several studies that compared the low-field and high-field MR images in musculoskeletal system. Kersting-Sommerhoff et al. reported 92% accordance of MR diagnoses between the low- and high-field for knee lesion and superior ability of the high-field to detect cartilage lesion (23). Taouli et al. concluded that high-field MRI and low-field dedicated MRI showed similar results in terms of cross-sectional grading of bone erosions, joint-space narrowing, and synovitis in the hands and wrists of patients with rheumatoid arthritis (24). Meanwhile, fat saturation might result in incomplete fat suppression in several conditions under low-field MR (25). Thus, the influences by low-field MR would be small.

In summary, symptomatic navicular in adolescents showed an edema-like bone marrow pattern on MR image. This pattern diminished with the alleviation of symptom managed non-operatively. Thus, MR images could be used for the diagnosis of symptomatic navicular and its intensity could monitor of the healing process, although MR would not be necessary for complete healing. Symptom occurred even at the navicular tuberosity without accessory navicular bone, which indicates different pathologic mechanism in adolescents is working, such as an osteitis or osteochondrosis.

CONFLICT OF INTEREST

No benefit or fund was received in support of this study.

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