Standing magnetic resonance imaging of distal phalanx fractures in 6 cases of Thoroughbred racehorse

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NOTE

Surgery

ABSTRACT. Six Thoroughbred racehorses with palmar process fractures of the distal phalanx were evaluated with standing magnetic resonance imaging (sMRI). In all the cases, the fractures were detectable on T1-weighted images and fat-suppressed images. Furthermore, multi-planar reconstruction images were useful for assessing the articular involvement of the fractures. Follow-up sMRI was obtainable in 3 cases, which revealed that the area of high signal intensity on fat-suppressed images decreased over time as symptoms improved. Our findings support the use of sMRI for the detailed evaluation of distal phalanx fractures including their articular involvement and the healing process.

KEY WORDS: distal phalanx, fracture, magnetic resonance imaging, racehorse

Fractures of the distal phalanx can occur from excessive impact during racing and exercise in racehorses; these fractures often require several months of rest and rehabilitation [15]. There are several types of fractures, and they are classified according to their anatomic locations [2]; Palmar process (wing) fractures are regarded as the most common types of fracture in racehorses. Type I fracture is a non-articular wing fracture, in which the fracture line does not extend up to the distal interphalangeal joint (DIPJ). Conversely, Type II fracture is an articular wing fracture, in which the fracture involves a larger portion of the distal phalanx, extending up the bone from the distal to the proximal aspect and reaching the articular surface of the DIPJ [16]. As the Type II fractures usually require a longer period of rest and may require corrective shoeing [8], the differential diagnosis of the fracture types is very important. Furthermore, during the period of rest and rehabilitation, it is recommended that the healing process is followed by diagnostic imaging to assist the rehabilitation program and to refine the prognosis [11].

The diagnosis of wing fractures involving the distal phalanx was made using radiography [1]. In the majority of cases, a fracture line can be detected as a linear area of increased radiolucency. However, the initial radiography may fail to detect the articular involvement of the fractures due to the insufficient time for bone resorption, especially in the cases of nondisplaced or hairline fractures [15]. These cases often require repeated radiography in a few weeks, or some other imaging modalities which may be useful in identifying the fractures [6, 7]. Moreover, it has been postulated that during rehabilitation, radiography alone may be insufficient to monitor the progress of healing, because the fracture lines sometimes remain visible for a period of time [3].

The use of magnetic resonance imaging (MRI) for the investigation of fractures of the distal phalanx was first described by using conventional MRI under general anesthesia [10]. However, limited information has been available in the literature regarding the findings of standing MRI (sMRI) in wing fractures of the distal phalanx [17]. It is expected that sMRI can produce multi-planar reconstruction images around the articular surface of the DIPJ, which would be clinically significant. Furthermore, follow-up sMRI is required to allow for the assessment of healing and for precise prognostication; however, the significance of these signal changes over time has not thoroughly described. The present study aimed to document the sMRI imaging characteristics of 6 Thoroughbred racehorses with fractures of the distal phalanx.

All horses were presented to the Racehorse Hospital, Ritto Training Center, between 2014 and 2017 for lameness evaluation. The diagnosis of wing fractures involving the distal phalanx was made using radiography (FCR Speedia CS, Fujifilm, Tokyo, Japan) and sMRI (Equine Limb Scanner; Hallmarq Veterinary Imaging, Ltd., Guildford, U.K.). The sMRI images were reviewed using the Digital Imaging and Communications in Medicine viewer OsiriX, version 5.8.2 (OsiriX Project, Geneva, Switzerland).
The sMRI findings of cases 1–6 are summarized in Table 1 together with the radiographic findings for comparison. Cases 1–4 had articular fractures, whereas cases 5 and 6 had non-articular fractures. The fractures appeared as a linear area of high or low signal intensity on T1-weighted images, and as a diffuse area of high signal intensity on fat-suppressed images. To differentiate between Type I and Type II fractures, the fracture line was further assessed on the multi-planar reconstructed images. The articular involvement was identifiable in cases 1–4.

In case 1, while it was vaguely identifiable in radiography that the fracture line reached the articular surface of the DIPJ (Fig. 1A), sMRI demonstrated a linear area of high signal intensity on T1-weighted image, clearly revealing the articular involvement on day 5 (Fig. 1B). Based on the result of sMRI, case 1 was treated with corrective shoeing, using a bar shoe. Additionally, the digital pulse, heat, and pain in the palmaromedial aspect of the right distal phalanx reduced over time, and case 1 returned to the first race on day 366, and the second race on day 386. Following the second race, case 1 exhibited lameness, and the second sMRI was performed on day 390, which revealed low signal intensity on T1-weighted images (Fig. 1D). Subsequently, case 1 returned to racing again on day 505.

Case 2 was diagnosed with type II fracture by radiography (day 1). For the assessment of the healing process, case 2 underwent sMRI repeatedly as follows: day 114 (Fig. 2B), day 158 (Fig. 2D), day 191 (Fig. 2F), day 262 (Fig. 2H), and day 353 (Fig. 2J). It was observed that a diffuse area of high signal intensity within the medial wing of the right distal phalanx decreased over time as the clinical symptoms improved. Based on the result of the fourth sMRI on day 262, case 2 resumed ridden exercises when the lameness was no longer recognizable during trotting, and there were no abnormalities on palpation. Case 2 resumed full training following the fifth sMRI on day 353. Unfortunately, case 2 exhibited repeat lameness on day 418 along with the recurrence of the clinical symptoms, and the reappearance of the fracture on radiography (Fig. 2K) and sMRI (Fig. 2L). Eventually, the owner chose to retire case 2 from racing.

Case 3 presented with left forelimb lameness after a race (day 1). Although heat and an increased digital pulse were palpable in the affected foot, there were no abnormalities detected by radiography on day 1 or day 7. Additionally, case 3 underwent sMRI on day 12, which revealed a linear area of high signal intensity surrounded by low signal intensity, STIR: short tau inversion recovery. The lameness is graded according to the American Association of Equine Practitioners scale (0–5). Grade 0 is sound and grade 5 describes the non-weight bearing horse.

Case 4 was admitted due to right forelimb lameness following a race (day 1). The palmar digital nerve block using 2% mepivacaine (Mepivacaine, AstraZeneca K.K., Osaka, Japan) was administered which eliminated lameness. Although a fracture

| Case | Day  | sMRI findings | Radiographic findings | Episode |
|------|------|---------------|-----------------------|---------|
| 1 (3yo, f) | 5 | T1: high within low (#), STIR: high | Linear area of increased radiolucency (Type II) | Lameness (grade 4) |
| 366 | - | - | Return to racing | |
| 386 | - | - | Race again | |
| 390 | T1: low, STIR: high | Linear area of slightly increased radiolucency | Lameness (grade 2) | Return to racing |
| 505 | - | - | |
| 2 (4yo, m) | 114 | T1: high within low (#), STIR: high | Linear area of increased radiolucency | Lameness (grade 4) |
| 158 | T1: high within low (#), STIR: high | Linear area of increased radiolucency | Lameness (grade 1) | Resume walking |
| 191 | T1: low, STIR: high | Linear area of increased radiolucency | Resume ridden exercise | |
| 262 | T1: low, STIR: limited area of high | Linear area of increased radiolucency | Resume full training | |
| 353 | T1: low, STIR: low | Linear area of slightly increased radiolucency | Lameness (grade 3) | Retired |
| 418 | T1: low, STIR: high | Linear area of increased radiolucency | Lameness (grade 4) | Retired |
| 3 (5yo, m) | 12 | T1: high within low (#), STIR: high | Linear area of increased radiolucency (Type II) | Lameness (grade 4) |
| 4 (3yo, f) | 5 | T1: high within low (#), STIR: high | Linear area of increased radiolucency (Type II) | Lameness (grade 4) |
| 5 (3yo, m) | 6 | T1: low, STIR: high | Linear area of mildly increased radiolucency (Type I) | Lameness (grade 3) |
| 98 | - | - | Return to racing | |
| 102 | T1: low, STIR: limited area of high | Linear area of slightly increased radiolucency | Lameness (grade 1) | Return to racing |
| 148 | - | - | Retired | |
| 6 (2yo, m) | 1 | T1: high within low (#), STIR: high | Linear area of increased radiolucency (Type I) | Lameness (grade 4) |
| Remarks: Still in racing (ran 6 more races after day 505) |

*Linear area of high signal intensity surrounded by low signal intensity, STIR: short tau inversion recovery. The lameness is graded according to the American Association of Equine Practitioners scale (0–5). Grade 0 is sound and grade 5 describes the non-weight bearing horse.
EQUINE MRI OF DISTAL PHALANX FRACTURES

Fig. 1. Dorsomedial palmarolateral oblique skyline radiographic images of the right distal phalanx of case 1 on day 5 (A), and day 390 (C). Arrows outline a linear fracture at the medial wing of the distal phalanx. It is vaguely identifiable that the fracture line reaches the articular surface of the distal interphalangeal joint (A; open arrow). On day 390, slightly increased radiolucency remains visible (C; open arrows).

T1-weighted images of the right distal phalanx on day 5 (B) and day 390 (D), reconstructed by multi-planar reformatting using image processing workstation. A fracture line within the medial wing of the distal phalanx is imaged as a linear area of high signal intensity on day 5 (B), clearly showing the articular involvement. The open arrow points to the middle phalanx (B). The fracture line is imaged as a linear area of low signal intensity on day 390 (D; open arrows).

line was visible by radiography, case 4 underwent sMRI on day 5 to evaluate the articular involvement; this was recognizable by sMRI as a linear high signal intensity extending to the DIPJ on T1-weighted image. Additionally, there was an area of low signal intensity within the medial wing that was imaged as a high signal intensity area on fat-suppressed images. Based on the result of sMRI, case 4 was retired for breeding purposes.

Case 5 presented with lameness following a race (day 1) and underwent sMRI on day 6, which showed an area of low signal intensity within the lateral wing of the right distal phalanx on T1-weighted images (Fig. 3B). The area was imaged as a diffuse area of high signal intensity on fat-suppressed images (Fig. 3C). Following the return to racing on day 98, case 5 underwent the second sMRI on day 102 due to the recurrence of lameness. The second sMRI demonstrated that the area of low signal intensity remained visible within the lateral wing on T1-weighted images (Fig. 3E). In contrast, there was a decrease in the area of high signal intensity on fat-suppressed images (Fig. 3F) which was visible on radiography as an area of slightly increased radiolucency (Fig. 3D). Case 5 raced again on day 148.

Case 6 presented with an acute onset of right forelimb lameness after exercise. Radiography detected a linear area of increased

Fig. 2. Dorsomedial palmarolateral oblique skyline radiographic images of the right distal phalanx of case 2 on day 114 (A), day 158 (C), day 191 (E), day 262 (G), day 353 (I), and day 418 (K). The fracture at the medial wing of the distal phalanx is evident until day 262 (G; arrows). On day 353, the area of slightly increased radiolucency remains visible (I; open arrows).

Frontal fat-suppressed images of the right distal phalanx on day 114 (B), day 158 (D), day 191 (F), day 262 (H), day 353 (J), and day 418 (L). The proximal and medial directions are at the top and right, respectively. A fracture at the medial wing of the right distal phalanx is imaged as a diffuse area of high signal intensity on day 114 (B; arrow). The area of high signal intensity decreases over time, and complete signal attenuation is observed on day 353 (J; open arrows). On day 418, re-fracture is suspected (K, L; arrows).
radiolucency within the medial wing of the distal phalanx. The area was observed as a linear high signal intensity surrounded by low signal intensity on T1-weighted images. Articular involvement was ruled out based on the reconstructed images which revealed that the linear high signal did not reach the DIPJ. However, on fat-suppressed images, the area had high signal intensity. Subsequently, the owner chose to retire case 6 following sMRI.

The fracture of the distal phalanx usually involves clinical signs, such as the sudden onset of moderate to severe lameness and an increased digital pulse and heat in the affected foot [3]. Clinically, diagnostic anesthesia may be performed to localize the origin of the lameness; however, in the current study, this was only performed in case 4 because marked heat and an increased digital pulse were palpable in the affected foot and because the pressure applied with hoof testers elicited a painful response on the sole. The degrees of clinical symptoms in the present cases corresponded well with the cases of distal phalanx fractures described in a previous report [12]. It has been suggested that the mean resting period required for the fractures of the distal phalanx is 6 to 12 months depending on the fracture types [5]. In non-articular wing fractures, conservative treatment would usually be successful [1]. Moreover, the prognosis for articular wing fractures was reportedly fair to good, with 69.6% of the horses being able to return to their original or expected level of use [14].

Additionally, a therapeutic shoeing method employing the use of rim shoe or a bar shoe can be applied to immobilize the articular fracture by preventing expansion of the hoof wall [8]. In the current study, case 1 was treated with a bar shoe. The articular involvement can be evaluated by radiography. However, because X-ray beams should be centered on the fracture, multiple oblique views may be necessary to visualize the fracture at the early stages or in cases of hairline fractures. Furthermore, it may require a few weeks before a whole fracture line becomes evident radiographically, because the fracture displacement or osteolysis occurring at the fracture margins, and the enlargement of the radiographic fracture gap over time, are the factors aiding the radiographic recognition of the fracture [4]. In case 4, a linear area of increased radiolucency became evident in the third radiography taken on day 12. From the results of the current study, it was presumed that sMRI could assist radiography, by detecting articular involvement at the early stage. Considering the clinical significance of the differentiation between articular fractures and non-articular fractures, the use of sMRI may be valuable as an aid for radiography, especially in the cases planned for therapeutic shoeing.

Recent advances in imaging modalities, such as computed tomography and nuclear scintigraphy, have improved the capability of identifying pathologies within the distal phalanx [6, 7]. These reports revealed that computed tomography and nuclear scintigraphy could be used to detect radiographically occult pathologies. During the healing process of distal phalanx fractures, a previous report indicated that radiological findings and clinical healing were not accurately correlated; therefore, clinicians might have to rely on their clinical impressions rather than radiological findings in order to formulate programs for rehabilitation [14]. In the current study, the follow-up sMRI of case 2 identified a decrease in the area of high signal intensity on fat-suppressed images prior to radiographically evident changes. Although this was based on the result from a single case, it was presumed that sMRI could be...
Fractures of the distal phalanx usually heal in 4 to 6 months [1]; however, the fracture line may be radiographically visible for much longer [14]. The healing begins with a fibrous union, which ossifies at 6 to 12 months. However, a nonunion may develop in some cases [4]; this could be attributed to the persistent mechanical loading of the horse’s weight on the affected foot as well as the unrestrained motion around the fracture site [18]. Therefore, the fracture can be a persistent cause of performance-limiting lameness in racehorses [4]. Based on the sMRI findings commonly seen in all cases, the common differential diagnoses include re-fracture, chronic fracture (delayed healing of the fractured bone), or a bone stress injury. These conditions which develop in the distal metacarpus/metatarsus are characterized by low signal intensity in the periphery of the lesion and a presence or absence of an associated linear high signal intensity on T1-weighted images; these features, along with a diffuse area of high signal intensity on fat-suppressed images [13] are consistent with the imaging characteristics of the present cases. From this, it was suggested that sMRI could be a useful tool for evaluating foot inflammation that may cause the recurrence of lameness.

In the present study, the fractures were imaged as a diffuse area of high signal intensity on fat-suppressed images in all the cases. This signal change was assumed to be related to the transient increase in osseous water content due to the hemorrhage and hyperemia caused by the fractures [17]. Case 1 and case 5 presented with recurrence of the clinical symptoms associated with the distal phalanx fractures; therefore, the second sMRI was performed which revealed a decrease in the areas of high signal intensity on fat-suppressed images. The short tau inversion recovery fast spin echo (STIR FSE) sequence, which uses a fat suppression technique, has been reported to be particularly useful for evaluating fat-based tissues, such as the trabecular bone [9]. This is theoretically accurate because the normally high signal of fat contained in the bone is suppressed in the fat suppression sequence, which allows the detection of bone lesions that would be inconspicuous in other sequences. Following the second sMRI, cases 1 and 5 resumed exercise and successfully returned to racing. The amount of time required for the return to racing was shorter following the first sMRI than the second sMRI in both cases (case 1: 365 days vs. 119 days and case 5: 97 days vs. 50 days). From this, it was inferred that the area of high signal intensity on fat-suppressed images could be interpreted as a useful landmark for formulating a prognosis. Hence, the assessment of the entire osseous edema using sMRI would offer reliable information to refine the prediction of clinical outcomes.

In conclusion, sMRI can be useful for the differential diagnosis of articular and non-articular wing fractures of the distal phalanx in Thoroughbred racehorses. Furthermore, by using sMRI, the fracture healing process can be effectively monitored despite the lack of radiographically evident changes.

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