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SHORT COMMUNICATION **Clinical Case Report**

Signal changes in standing magnetic resonance imaging of septic pedal osteitis in a Thoroughbred racehorse

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Abstract

Septic pedal osteitis refers to bacterial infection within the distal phalanx, which requires effective surgical intervention. A 3-year-old Thoroughbred colt underwent standing magnetic resonance imaging (sMRI) on the 10th day after admission (day 10), which revealed hyperintensity beneath the inner hoof wall in sagittal T2*-weighted and transverse T2-weighted sequence, suggesting abscess formation. On day 25, the second sMRI indicated development of osteitis, in which the lesion extended into the distal phalanx. This lesion was imaged as hyperintensity on T1-weighted, T2*-weighted and T2-weighted images. On day 59, laminitic changes were evident on T1-weighted and T2*-weighted images. Our case report suggests that sMRI could allow better understanding of the disease process than other conventional imaging modalities, and guide early surgical intervention.

Key Words: magnetic resonance imaging, osteitis, racehorse

Septic pedal osteitis (SPO) is defined as a disease that involves osseous infection with bacteria, commonly from penetrating objects, surrounding soft tissues or hematogenous source[1,12,15]. Treatment involves administration of antimicrobials, together with surgical debridement of the infected bone[3,7,12]. As the osseous infection progresses, a sequestrum may develop, which could lead to longer treatment periods[1,3]. Therefore, early surgical intervention is considered to be essential. Surgical debridement of the infected bone is also important for the collection of bacteriological sample to initiate effective antimicrobial therapy based on the sensitivity result. On the other hand, in a clinical environment, diagnosis of SPO sometimes relies on clinical signs, such as increased hoof temperature, prominent digital pulse and chronic

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lameness, all of which are not indicative to differentiate other foot abnormalities. Characteristic radiographic findings in SPO include development of radiolucent area, loss of trabecular details and/or resorption of the solar margin, all of which represent osteolysis[7,12]. However, at least 40 % of the mineral content of bone must be lost before lysis becomes radiographically apparent[3]. This may suggest that radiography is not a sensitive technique and could fail to identify SPO at an early stage.

Magnetic resonance imaging (MRI) was first introduced to equine practice in 1997, followed by development of equine-dedicated standing low-field MRI (sMRI) in 2002. The sMRI allows scanning under sedation. In a clinical environment, the advantages gained from avoiding risk and cost of general anesthesia are considered to outweigh the limitations of resolution with the lower magnetic field strength and sMRI has been used for specific diagnosis of bone and soft tissue abnormalities within foot[17]. According to the study by Urraca del Junco *et al.*[17], it was indicated that sMRI could detect lesions that were not identifiable with radiography, and provide more appropriate prognostication. To the best of the authors' knowledge, there are no previously reported cases of SPO repeatedly assessed with sMRI. The aim of this study is to describe imaging characteristics of a SPO case identified and monitored over time with sMRI, and to relate the findings to the result of radiography.

A 3-year-old Thoroughbred colt was admitted to the Racehorse Hospital, Ritto Training Center for evaluation of a right forelimb lameness (day 1). At examination, the lameness was apparent at walk, and there was increased digital pulse pressure. Also, pressure with hoof testers (NFC540, Fujihira Industry Co., Ltd, Tokyo, Japan) elicited a painful response on the sole. There were no particular findings in radiography of the foot. A 10-day course of oral diclofenac sodium (1 mg/kg; Blesin Tablets, Sawai Pharmaceutical Co., Ltd, Osaka, Japan) did not improve the heat and the pain in the foot. On day 10, the foot was examined with radiography and sMRI (0.27 Tesla, Hallmarq Equine Limbscanner, Hallmarq Veterinary Imaging, Ltd., Guilford, UK). Although there were no abnormalities in radiography (Fig. 1, A), a hyperintense area was detected just beneath the inner hoof wall on sagittal T2*-weighted gradient echo (TE: 13 msec, TR: 34 msec, Flip Angle: 25°, FOV: 170 mm, Slice Thickness: 3 mm, Matrix Size: 340×130, Number of Averages: 1) and transverse T2-weighted fast spin echo (TE: 88 msec, TR: 1681 msec, FOV: 170 mm, Slice Thickness: 5 mm, Matrix Size: 336×175, Number of Averages: 3) images (Fig. 1, C, E). This area had hypointensity on T1-weighted gradient echo (TE: 7 msec, TR: 24 msec, Flip Angle: 43°, FOV: 170 mm, Slice Thickness: 3 mm, Matrix Size: 340×170, Number of Averages: 1) sequence (Fig. 1, B, D). Following the examination, the medial hoof wall was resected under general anesthesia, which resulted in discharge of purulent material (Fig. 2, A). Intravenous regional limb perfusion of antimicrobials using either 1 g of Amikacin (Amikacin Sulphate for injection, Nichiiko Co., Ltd., Toyama, Japan) or 350 mg of Marbofloxacin (Marbocyl, Meiji Seika Pharma Co., Ltd., Tokyo, Japan), and lavage of the surgical site had been performed daily following the surgery for 15 days. On day 25, the lameness did not resolve completely despite the treatments, and the second sMRI revealed that the hyperintense area was enlarged extending into the distal phalanx on T2*-weighted and T2-weighted images (Fig. 1, H, J). The area had hyperintensity surrounded by the bone with hypointensity on T1-weighted images (Fig. 1, G, I). The distal phalanx was no longer parallel to the hoof wall (Fig. 1, F). Subsequently, the hoof wall was further resected under sedation to debride infected pedal bone, and also to make draining tract from the bone (Fig. 2, B). The swab sample was submitted for bacteria culture and sensitivity tests. From the sample, 5.0×10^6 (CFU/swab) of *methicillin-resistant Staphylococcus*

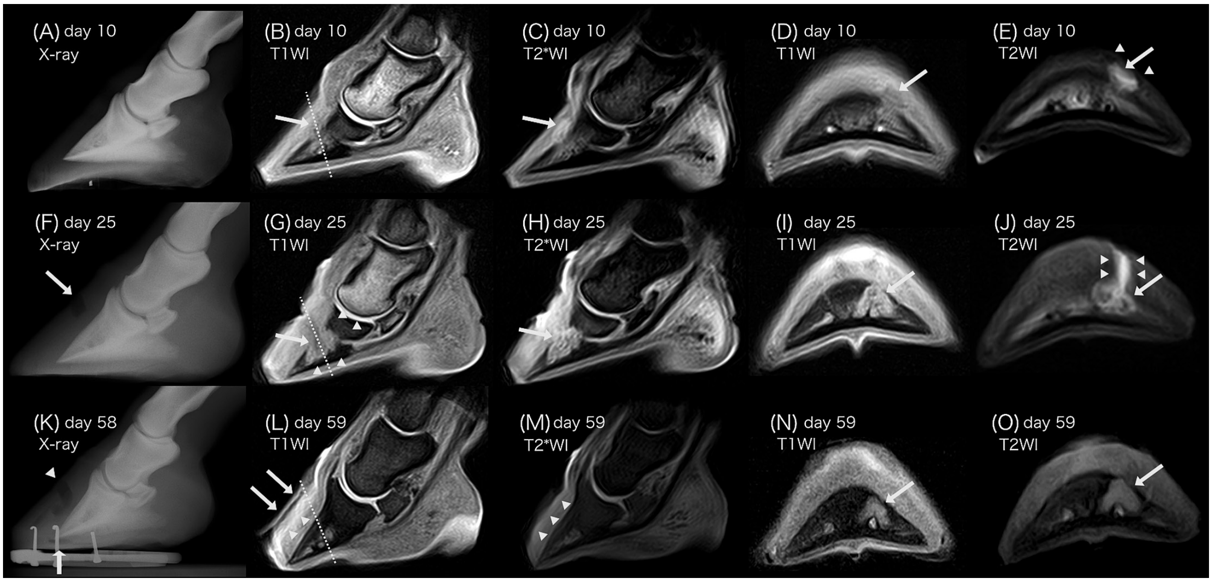

Fig. 1. (A) Lateromedial radiographic image of the foot on day 10. There are no abnormalities. (B) Parasagittal T1-weighted, and (C) T2*-weighted images of the foot on day 10 with a dashed line showing the level of the section for the transverse images (D) and (E). In the T1-weighted sequence, there is a focal hypointense area in the laminae (B, arrow), corresponding with a hyperintense region (C, arrow) on the T2*-weighted image. (D) Transverse T1-weighted, and (E) T2-weighted images of the distal phalanx on day 10. Medial is to the right. There is a focal hypointense area within the laminae (D, arrow) on the T1-weighted image. In the T2-weighted sequence, this area is occupied by hyperintensity (E, arrow), surrounded by irregular outline of hypointensity (E, arrowheads), suggesting abscess formation beneath the inner hoof wall. (F) Lateromedial radiographic image of the foot on day 25. The resected hoof wall is imaged as a rectangle-shaped radiolucent area. The distal phalanx is no longer parallel to the hoof wall. (G) Parasagittal T1-weighted, and (H) T2*-weighted images of the foot on day 25, showing hyperintensity in the distal phalanx (G, H, arrow). Note that the surrounding bone has hypointensity (G, arrowheads) in the T1-weighted sequence. A dashed line shows the level of the transverse section, corresponding with the images (I) and (J). (I) Transverse T1-weighted, and (J) T2-weighted images of the distal phalanx on day 25. Medial is to the right. There is hyperintensity in the distal phalanx (I, J, arrow) in both sequences. A linear hyperintense area within the laminae (J, arrowheads) reflects purulent material on the T2-weighted image. (K) Lateromedial radiographic image of the foot on day 58. The dorsal wall of the hoof is no longer parallel with the dorsal surface of the distal phalanx. The radiolucent 'L-shaped' zone (K, arrowhead) corresponds with a draining tract made by wall resection surgery. The linear radiolucent lesions within the dorsal aspect of the hoof wall and the sole (K, arrow) represent lamellar separation, and subsolar abscessation, respectively. (L) Sagittal T1-weighted, and (M) T2*-weighted images of the foot on day 59 with a dashed line showing the level of the transverse section. Note angular deviation between the dorsal aspect of the distal phalanx and the hoof wall, showing rotation of the distal phalanx. There is hyperintensity within the lamellar interface, suggesting formation of lamellar wedge (L, M, arrowheads). In the T1-weighted sequence, there is linear hypointense area (L, arrows) consistent with hoof wall separation. (N) Transverse T1-weighted, and (O) T2-weighted images of the distal phalanx on day 59. Medial is to the right. The hyperintensity in the distal phalanx (N, O, arrow) remain visible in both sequences.

aureus (MRSA) were isolated. Based on the sensitivity, 1.6 g of Trimethoprim and 8 g of Sulfamonomethoxine (Bactramin, Chugai Pharmaceutical Co., Ltd., Tokyo, Japan) were administered orally once a day from day 29 to day 58. Additionally, maggot debridement therapy[11) was initiated expecting to control infection and remove necrotic tissue until day 53 when a reddish-brown exudate was no longer present. By day 58, the number of MRSA isolates was decreased to 8.5×10^3 (CFU/swab). On day 59, however, the third sMRI detected displacement of the distal phalanx and hyperintensity within the lamellar interface on T1-weighted and T2*-weighted images (Fig. 1, L, M). The pedal bone rotation was also visible radiographically on day 58 (Fig. 1, K), and deteriorated to severe downward rotation with the dorsal angle of 12 degrees on day 67 (Fig. 3, A). The serious pain due to the progression of laminitis was uncontrollable,

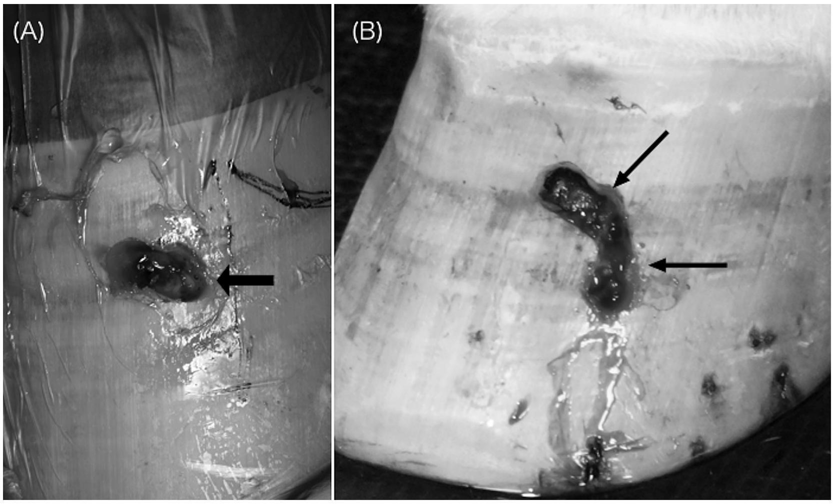

Fig. 2. (A) Photograph obtained during surgery on day 11, showing a hole (2 × 1 cm) in the medial hoof wall with discharge of purulent material. (B) Photograph of the foot on day 25 when the hoof wall has further been resected to debride infected pedal bone. The hole has been enlarged to 3 × 3 cm.

and the colt was euthanized on day 67.

In histology, hoof wall separation, separation of epidermal laminae from dermal laminae and formation of lamellar wedge were observed, indicating chronic laminitis (Fig. 3, B). Another particular finding was focal bone resorption at the site of osseous infection. The bone was replaced by connective tissue, and accumulation of lymphocytes was observed (Fig. 3, C, D). MRSA were no longer isolated from the sample obtained after euthanasia.

In the present study, the source of bacterial infection that lead to SPO remained unclear. According to previous studies, foreign objects from penetration injuries, prolonged infection on surrounding soft tissues within hoof capsule and bacterial transmission via circulation could be the major causes for SPO[1,12,15]. The present case had no history of foot penetration nor histological findings in other organs that suggested septicemia. Therefore, although not confirmed, it was speculated that abscess just beneath the inner hoof wall which was detected by the first sMRI could be associated with the development of SPO.

In human medicine, MRI is used for evaluation of septic arthritis and osteomyelitis[8,9]. In equine medicine, high-field MRI characteristics of 14 septic arthritis cases have been reported[6]. Some of the horses in this reported study developed osteomyelitis, of which signal changes were similar to those in human, characterized by hyperintensity on T2-weighted sequence and hypointensity on T1-weighted sequence. However, there has been insufficient information so far available whether MRI could distinguish septic from aseptic osteitis. In the present case, bacterial involvement was confirmed by bacteria culture from the debridement sample, and sMRI was considered to aid in the evaluation. Further study is warranted for evaluation of the usefulness of contrast enhancement technique in such differential diagnoses.

SPO cases diagnosed using MRI have previously been reported[2,17]. Hyperintensity on T2-weighted images within the distal phalanx was described as the characteristic signal change for the diagnosis of SPO, which was also observed in the present case. According to a different study that described MRI characteristics of septic arthritis, hypointensity within subchondral bone, consistent with bone sclerosis was identified on T1-weighted images in majority of the horses[6]. The present case involved such signal changes. Generally, it could take 1 to 2 weeks before osseous changes become radiographically evident[16]. Hence,

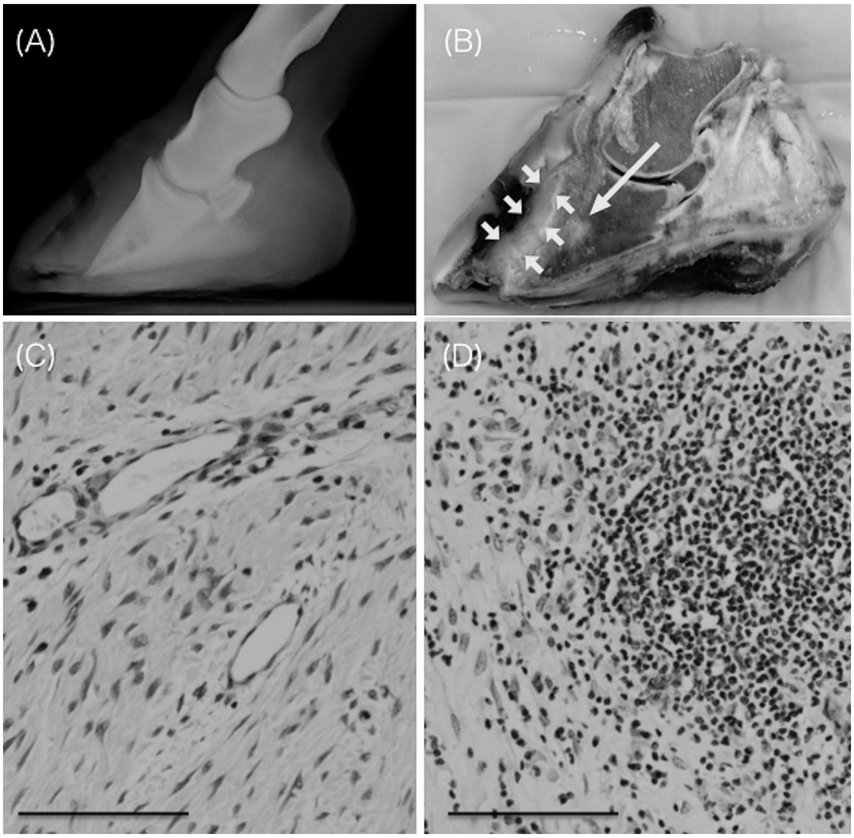

Fig. 3. (A) Lateromedial radiographic image of the foot on day 67, showing severe downward rotation of the distal phalanx with the dorsal angle of 12 degrees. (B) Parasagittal section of the foot. Note the lamellar wedge that forms from remaining laminar epithelial cells following rotation of the distal phalanx (B, small arrows). There is a focal osteolytic lesion within the dorsal margin of the distal phalanx replaced by yellowish connective tissue (arrow). (C) Histology of a section of infected pedal bone. There is a focal area of bone resorption. (D) The area is replaced by connective tissue. Note lymphocytes accumulation. H&E stain; bar = 100 mm.

MRI has been proved to be useful for detecting bone pathology in human medicine[10], and equine medicine[5]. In the present case, as the clinical condition deteriorated, the hyperintense area was enlarged and observed within the distal phalanx in T1-weighted, T2*-weighted and T2-weighted sequences. From this, it was indicated that sMRI could be used to monitor the condition of SPO.

Despite that the present case bore its weight mostly on the contralateral limb over a period of time due to serious pain in the affected limb, interestingly, laminitis was developed in the affected limb. It has been shown that in the disease process of laminitis, integrity of lamellar tissue that functions as suspensory apparatus of the distal phalanx is compromised, eventually leading to failure of the connection between hoof and bone[14]. Therefore, in the present case, development of laminitis could be associated with loss of the mechanical attachment force as a result of excessive hoof wall resection. Further, prolonged lamellar inflammation from MRSA infection was suggested to exacerbate laminitis[13]. Gross pathology result of the present case indicated the contralateral limb had no evidence of laminitis. Based on the above findings, for the prevention of laminitis in chronic SPO cases, particular care should be given to the affected limb as well as the contralateral limb. This includes minimal resection of hoof wall to maintain mechanical attachment force.

Laminitic changes were evident both in radiography and sMRI. In sMRI, formation of lamellar wedge was observed as hyperintensity within the enlarged lamellar tissue on T1-weighted and T2*-weighted images. Also, the displacement of the distal phalanx was imaged as angular deviation between the dorsal aspect of the distal phalanx and the hoof wall. These changes corresponded well with the findings in previous studies[4]. To the best of our knowledge, this is the first report describing sMRI findings of SPO in a Thoroughbred racehorse that eventually developed laminitis.

In conclusion, sMRI can be a valuable diagnostic tool for detailed evaluation of the disease process of SPO with guiding surgical intervention.

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