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CASE REPORTS

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Bone Marrow Edema Caused by Altered Pedal Biomechanics

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ABSTRACT

Objective: To review the magnetic resonance imaging (MRI) appearance of bone marrow edema (BME) and to discuss the applications of this imaging modality in the diagnosis of associated disorders. A case of BME in the foot is also provided to acquaint the reader with how MRI may assist in establishing a differential diagnosis in patients with normal radiographs and clinical findings that suggest osseous injury.

Clinical Features: A 42-yr-old woman suffered from persistent pain along the dorsum of her foot that worsened with jogging. There was foot pronation and palpable pain and swelling at the third tarsometatarsal joint. An MRI was performed, but it was initially misinterpreted. A second review of the MRI examination established the presence of stress-induced BME adjacent to the articular margins of the third tarsometatarsal joint.

Intervention and Outcome: Medical treatment consisted of a cortisone injection into the left third tarsometatarsal joint, which provided transient relief. Chiropractic treatment included flexible custom orthotics prescribed to specifically address her foot pronation. This was the only chiropractic treatment employed.

Conclusion: In the presented case, the sensitivity of MRI to stress-induced BME identified the cause of this patient's symptoms and, more importantly, directed management. Because of its ability to demonstrate anatomic and physiologic information, MRI is the ideal imaging modality for assessing suspected injury to the osseous tissues. In patients who relay historical information that suggests chronic or acute osseous injury but demonstrate no radiographic changes to support the clinical suspicion of bony abnormality, an MRI may be indicated to exclude occult injury. (J Manipulative Physiol Ther 1997; 20:56–9).

Key Indexing Terms: Magnetic Resonance Imaging (MRI); Foot Injuries, Orthotic Devices

INTRODUCTION

Humans stand and walk upright against the forces of gravity. Undue stress to the human skeleton, of either an acute or chronic nature, may manifest itself differently in the soft tissues and bony structures of each individual. Chronic stress may induce degenerative osteoarthritis with nonuniform joint space narrowing (caused by cartilage deterioration), subchondral sclerosis and osteophyte formation. These changes are usually seen with plain film radiographs.

A more challenging clinical presentation is the acute or subacute patient in which the initial plain films are normal, yet the patient is symptomatic. In this clinical circumstance, special imaging modalities, such as nuclear medicine (bone scan) and magnetic resonance imaging (MRI) may identify radiographically occult pathology. It is with this concept in mind that we present an interesting case report of stress-induced bone marrow edema (BME) in the foot. An overview of management and current imaging modalities is discussed. Fracture-induced BME and bone contusion (bone bruise) and their imaging characteristics are also reviewed.

CASE REPORT

History

A 42-yr-old woman suffered from a 10-month history of persistent left-foot pain that initially occurred while performing aggressive yoga exercises. She felt immediate sharp pain that later subsided. Three days later, while jogging her usual 2 miles (which she did 4 days/wk), she felt sharp, intense pain in the same area, which caused her to stop running and consult a physician.

Previous Medical History

Initially, the patient visited a podiatrist, who performed an exam, X-rayed the area of complaint and referred her for an MRI scan of the left foot. The X-rays showed no abnormalities and the MRI was interpreted to show no evidence of pathology. Follow-up radiographs were performed 2 wk later in an effort to confirm a clinical diagnosis of suspected stress fracture; however, these films were also negative. At that time, the podiatrist elected to inject the left third tarsometatarsal joint

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with cortisone. This provided temporary relief of her pain. One month later, the patient consulted two different orthopedic surgeons because of recurrent pain.

The first orthopedic surgeon noted slight soft tissue edema of the left third tarsometatarsal joint and a palpable defect in the extensor tendon. A nodular swelling was noted adjacent to the defect and was thought to represent a ruptured tendon. A recommendation was made for surgical exploration of the foot. The patient was informed that if the surgery failed, the joint could be fused with a second operation, which would then make it stable.

Because these recommendations perplexed and confused the patient, she sought a second opinion from another orthopedic surgeon. He reviewed the patient's previous images and ordered follow-up posteroanterior and medial oblique radiographs of the left foot; these were interpreted as normal. He was not in agreement that surgical intervention was indicated and, because of the lack of conclusive findings, suggested a "wait-and-see" approach, concluding that surgery should be the last option.

Fig. 1 *Plain film: medial oblique radiograph of the foot. There is no osseous or joint disease identified. Particular attention to the base of the third metatarsal articulation shows no abnormality (Courtesy of Dale G. Huntington, D.C., D.A.B.C.O., Springdale, Arkansas.)*

Physical Examination

The patient's vital signs and regional neurological examination were unremarkable. Visual inspection of the left foot revealed a 10° flexion deformity of the third tarsometatarsal joint along with pronation of the medial longitudinal arch. A small, semi-hard nodule was palpated at the third tarsometatarsal joint, over the extensor digitorum tendon. This nodule was tender to moderate pressure. Increased pain at the third tarsometatarsal joint was experienced during toe walking.

Imaging Analysis

Because of the complexity of this patient's case, the examining chiropractor forwarded the patient's imaging studies to chiropractic radiologists for a second opinion. Plain film radiographs dated June 9, 1994 (Fig. 1), and December 16, 1994, along with an MRI scan of the left foot dated May 31, 1994 (Fig. 2), were submitted for review. The plain films showed no evidence of osseous or joint disease. Bony alignment was adequate. There was no evidence to suggest stress fracture on any of the plain film radiographs.

The left foot MRI was read as normal by the institution that performed the scan. However, close inspection of the T_2-weighted sagittal images revealed a small area of high signal intensity within the bone marrow adjacent to the margins of the third tarsometatarsal joint. This area of bright signal directly correlated with the patient's focal symptomatology and was consistent with an area of BME.

We concurred that surgical intervention was not necessary at present. Further postural examination of the foot and ankle was recommended in an effort to detect any static or dynamic biomechanical abnormalities.

Treatment

As a result of the postural examination findings of foot pronation, we made a cast of the patient's foot in the weight-bearing position and a custom-made flexible orthotic was prescribed to specifically address her foot pronation (Orthotics provided by Foot Levelers, Inc., Roanoke, VA; Full-Length Firm Flex Plus). These orthotics were placed in the patient's running shoes, as well as daily work shoes, and no other form of therapy was rendered. She resumed her normal daily activities, with the exception of jogging. In less than 1 month, her foot pain had completely subsided and she was able to return to full activity (including the restoration of her 2-mile jogs). A follow-up MRI was not clinically indicated because of her quick and complete response to the orthotics. At 1-yr follow-up, the patient remained asymptomatic and continued to enjoy her previous athletic activities.

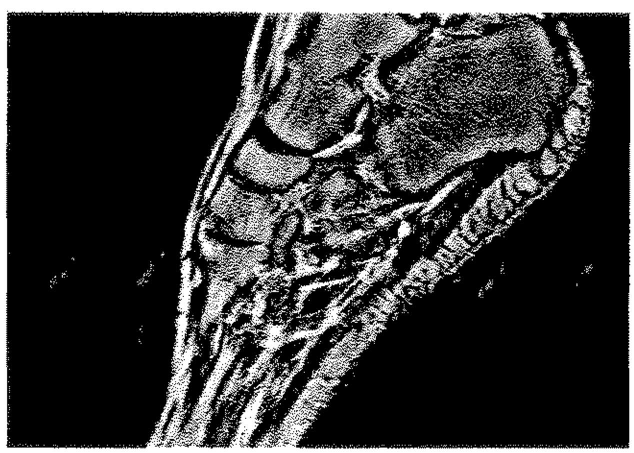

Fig. 2 *MRI scan of the foot: T_2-weighted sagittal image. Observe the area of bright signal intensity within the marrow adjacent to the margins of the third tarsometatarsal articulation* **(arrow)**. *These signal alterations are consistent with BME (Courtesy of Dale G. Huntington).*

DISCUSSION

The discovery and development of MRI is the most significant milestone in medical imaging since William Conrad Roentgen's discovery of the X-ray in 1895. MRI, like computed tomography (CT), is capable of providing an axial demonstration of human anatomy, but also shows superb anatomic detail in the sagittal, coronal and even oblique imaging planes. This process occurs in the absence of ionizing radiation. Comparatively, CT provides only a morphological assessment of the area imaged, while MRI displays both morphology and physiology. Nuclear scintigraphy and MRI are both sensitive methods of obtaining physiological data within the bone and surrounding tissues, but only MRI is capable of displaying this information without using radiopharmaceutical agents. Standard spin echo pulse sequences and specialized fat suppression MR techniques make this the most sensitive imaging modality in evaluating localized changes within the bone marrow and adjacent soft tissues. MRI also has multiplanar capabilities, enabling anatomic information to be extracted from virtually any location without altering the patient's position within the scanner.

A recent study by Schweitzer and White from Thomas Jefferson University Hospital in Philadelphia, Pennsylvania, evaluated the effects of forced foot pronation on 12 asymptomatic volunteers using specialized serial MR images (1). They found that after just 2 wk of enforced foot pronation, physiologic changes consistent with BME were observed in the weight-bearing bones of the lower extremity. Moreover, 2 wk after the pronation device was removed and the patients were allowed to ambulate normally, all three subjects that underwent follow-up MR scans showed resolution of the BME pattern. This new information shows the almost immediate effects of altered biomechanics of the foot and ankle.

MRI provides a unique yardstick for the early assessment of physiological changes in bone. Certainly, the skeleton is not the only anatomic structure that is exposed to sustained abnormal stress associated with pronation of the medial longitudinal arch. This must be kept in mind by all clinicians who routinely evaluate and render treatment to patients with low back and/or lower extremity pain. All patients with these symptoms should have a physical examination of the kinetic chain to rule out altered lower extremity biomechanics and foot pronation (2-5).

Schweitzer and White's study proves that there are detrimental effects associated with an abrupt alteration in the biomechanics of the weight-bearing bones and joints, as well as the rapid benefits achieved with the restoration of normal function (1). Their study also provides direct evidence of the specific effects of excessive pronation at the foot and ankle on the bones of the lower extremities up to the level of the proximal femur and hip joint, a concept not yet universally accepted by clinicians.

Spine—Old Fracture vs. New: A New Look at an Old Problem

Patients with complicated histories of numerous bouts of trauma and multiple compression deformities present a challenge to the clinician, who must then determine whether a given deformity is old or new. This dilemma is commonly encountered in clinical practice. These fractures are usually seen on plain film radiographs as wedge-shaped (triangular) or biconcave deformities. Radiographs are often helpful; however, step defects and radiodense bands of trabecular condensation are unreliable signs of determining the age of a compression fracture. Vertebral wedging is found in both old and new fractures, and reinstatement in height of the vertebral body, even in healed fractures, does not occur.

MRI provides the information necessary to distinguish between old and new compression deformities (6). In acute and subacute injuries (less than 6 wk old), hemorrhage or edema within the vertebral body marrow will be low in signal on T_1-weighted images, become hyperintense with T_2-weighting and even brighter with fat suppression techniques (Fig. 3). A chronic or long-standing fracture does not demonstrate these characteristic signal changes.

Limited MRI Scan: A New Concept

We recently suggested that sagittal MR images using T_2-weighted spin echo or fat suppressed techniques be performed to assess vertebral compression deformities thought to be of recent onset (7). This limited examination can be performed in 15 min and will unequivocally determine the presence or absence of BME within the vertebral body. The reduced cost of this exam makes it more cost-effective than bone scan or CT and it renders no radiation dose to the patient. If any pathology beyond edema is identified, additional axial and sagittal images should be obtained for complete evaluation. This limited MRI scan concept has also been described in assessing the hip for radiographically occult fractures (7).

Knee

MRI is the most comprehensive imaging modality for evaluation of both osseous and soft tissue structures of the knee. Not only are the ligaments, menisci and other supportive soft tissues about the knee well visualized, but the BME pattern, with or without associated fracture, may be observed (Fig. 4) (8, 9). Patients suffering from an acute traumatic injury to the knee joint often demonstrate positive orthopedic signs of injury. Unfortunately, standard radiographs are usually normal, with the exception of fracture. Some patients exhibit clinical evidence of bone injury and require additional imaging to determine if an injury is, in fact, present. Radiographically occult osseous injury can be excluded, and information regarding the adjacent soft tissues can be assessed noninvasively with MRI.

CONCLUSION

MRI is helpful in identifying occult pathology, such as bone marrow edema. BME may occur with numerous pathologic conditions, including acute trauma and long-standing stress. Recognition of this characteristic pattern of altered bone phys-

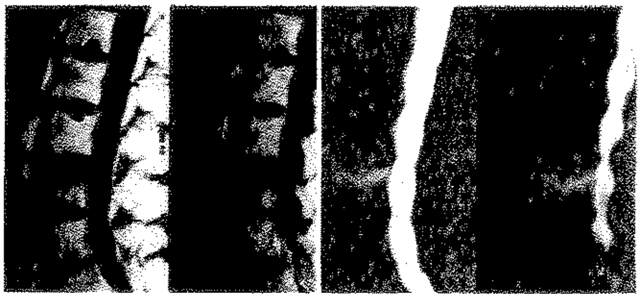

Fig. 3 *Lumbar spine MRI:* ***Left,*** *T_1-weighted sagittal image.* ***Right,*** *T_2-weighted sagittal image. There is a large area of low* **(black)** *signal intensity affecting the bone adjacent to the superior vertebral endplate L4. This area becomes bright* **(white)** *with T_2-weighting. These imaging findings are consistent with bone marrow edema associated with an acute L4 vertebral body fracture.*

iology may assist in the early diagnosis and management of such disorders.

An interesting case study of a patient with persistent left foot pain caused by foot pronation is described. The use of customized flexible orthotics corrected her altered pedal biomechanics and ultimately restored proper joint function, resulting in complete abatement of symptoms. At 1-yr clinical follow-up, the patient remained asymptomatic and continued to enjoy normal physical activities.

The imaging evidence of this patient's stress-induced injury is similar to the recently published scientific article by Schweitzer and White (1). They observed that bone physiology is quickly altered by changing the biomechanical function of weight-bearing structures. We observed similar changes here. This raises the question of whether long-term postural misalignments may have the same detrimental effects on the bony or supportive soft tissue structures of the human frame. Further research in this area is necessary.

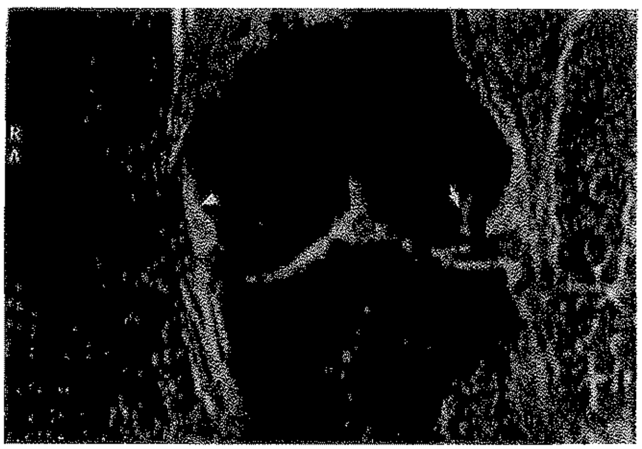

Fig. 4 *MRI scan of the knee: T_2^*-weighted coronal image. Observe the interruption of the thin, low signal intensity medial collateral ligament* **(black arrow)**. *The ligament is displaced from its attachment on the medial tibial condyle by a collection of high-signal-intensity hemorrhage and edema* **(white arrowhead)**. *Also note the hyperintense signal within the subchondral bone of the lateral femoral condyle, consistent with a bone contusion* **(white arrow)** *(Courtesy of Kenneth B. Reynard, M.D., Center for MRI, Ltd., Denver, Colorado).*

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