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ORIGINAL ARTICLE

Focal Bone Lesions Following Ultrasound Diathermy: Case Series

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ABSTRACT

Introduction: *We sought to describe focal bone lesions detected on magnetic resonance imaging (MRI) in patients following ultrasound diathermy.*

Methods: *We performed a retrospective analysis of MRI characteristics of bone lesions in 10 patients who underwent ultrasound diathermy for musculoskeletal conditions followed by plain radiographs and MRI for pain. Magnetic resonance arthrography was performed in two patients and one patient had a second follow-up MRI examination. A phone interview was conducted with all patients.*

Results: *All 10 patients had experienced mild to severe pain during ultrasound diathermy, with four (40%) prematurely terminating the treatment session as a result. Plain radiographs were normal. On MRI, a total of 12 lesions were observed in the 10 patients, with nine lesions in eight shoulder joints, two lesions in one ankle joint, and one lesion in the first metacarpal base. All lesions were small to medium-sized (6 × 5 × 3 mm to 32 × 23 × 9 mm), well-demarcated and subcortical in location with a crescentic or oblong configuration. Lesions were highly conspicuous on T2-weighted images and relatively inconspicuous on T1- or intermediate weighted sequences. Typically, larger lesions had a T2-hyperintense rim surrounding an isointense central area. Leakage of arthrographic contrast into the lesion was observed. The overall features favoured focal osteonecrosis in all cases. The affected locations typically had little overlying subcutaneous tissue, were close to tendon insertions, and corresponded to the site of ultrasound diathermy application in all patients.*

Conclusion: *Appearances akin to focal osteonecrosis may result from application of ultrasound diathermy. Recognition of the characteristic appearance will allow this connection to be made to avoid subsequent unnecessary workup.*

Key Words: *Bone diseases; Diathermy; Magnetic resonance imaging; Ultrasonography*

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中文摘要

超聲波透熱療後的局灶性骨病變：病例系列報告

蔡紹俊、李嘉樂、譚國偉、容樹恒、JF Griffith

引言：本研究旨在描述超聲波透熱療後患者在磁共振成像（MRI）檢測的局灶性骨病變。

方法：我們回顧分析10名因肌肉骨骼疾病接受超聲波透熱療的患者的骨病變MRI 特徵，隨後通過X光平片和MRI進行疼痛檢查。對兩名患者進行MR關節造影，一名患者進行第二次隨訪MRI。對所有患者進行電話訪談。

結果：所有患者在超聲波透熱療期間都出現中度至劇烈疼痛，其中4名患者（40%）因此提前終止治療。X光平片結果無異常情況。10例患者於MRI檢查發現共12個病灶，其中肩關節8例共9個病灶、踝關節1例共2個病灶，以及第一掌骨基部1個病灶。所有病灶屬細至中等大小（介乎6 × 5 × 3 mm至32 × 23 × 9 mm），邊界清楚且位於皮質下，呈新月形或橢圓形。病變在T2加權圖像上非常明顯，在T1加權或中間加權序列上相對不明顯。較大的病灶通常在等信號中心區域邊緣呈T2高信號，以及關節造影顯影劑滲出病灶。所有病例的整體特徵有利局灶性骨壞死。受影響位置通常幾乎沒有覆蓋的皮下組織、靠近肌腱插入處，且與所有患者的超聲波透熱療應用部位對應。

結論：類似局灶性骨壞死的外觀可能由於使用超聲透熱療所致。識別這種特徵外觀有助避免不必要的後續檢查。

INTRODUCTION

Musculoskeletal symptoms including pain, tenderness, and restricted movement, are common indications for referral to physiotherapy treatment. One of the physiotherapy treatments used to relieve inflammation and promote healing is the application of heat treatment either in the form of hot packs or deep heat diathermy.[1-3] Deep heat diathermy can be achieved using therapeutic ultrasound, shockwaves, or microwaves.[4,5]

Some studies have indicated ultrasound diathermy to be effective[4,6] while others show no demonstrable benefit.[7,8] Ultrasound diathermy can result in thermal injury to the skin, subcutaneous tissue and muscles.[1-3] An uncommon complication of diathermy is injury to the cortical bone, causing osteonecrosis.[9] During the past 3 years, we encountered 10 patients who had received diathermy treatment and had bone lesions visible on subsequent magnetic resonance imaging (MRI) examinations performed for pain. These bone lesions were identical to the osteonecrosis previously reported as being related to diathermy treatment.[9] Some of these bone lesions were not initially recognised as being possibly iatrogenic, prompting unnecessary additional investigations. The aim of this study was to both review the magnetic resonance (MR) appearances of these lesions, and to increase awareness of their occurrence and significance.

METHODS

Patients who presented to our institution in 2018 and 2019 with symptomatic bone lesions of the shoulder, ankle, or wrist following diathermy treatment were identified and reviewed. All patients had been referred for musculoskeletal joint symptoms following diathermy. For all patients, radiographs of the symptomatic sites taken before MRI examination showed no abnormalities.

After MRI examinations, all patients underwent a telephone interview conducted by one of the authors (RKLL). Specific features queried during this interview were whether ultrasound diathermy was performed, the time lag between diathermy and MRI, the number of diathermy sessions, and the pain level (mild, moderate, severe) during the diathermy session.

MRI examinations were performed on a 1.5 T MRI scanner (Ingenia 1.5T MR System; Philips, Best, the Netherlands) in one of two imaging centres using standard joint imaging protocols. Two patients underwent MR arthrography and one patient had a subsequent

follow-up MRI examination. Intravenous contrast was not administered to any patient. All MR examinations were analysed by two musculoskeletal radiologists with 3 and 29 years' experience, respectively. Features noted were the appearance of bone lesion on T1-, proton density, and T2-fat-saturated sequences; lesion number, location, configuration, and dimensions; as well as the appearance of the overlying soft tissue. The relationship between lesion volume (width × depth × length × 0.52) or maximum depth and lesion appearance was analysed.

RESULTS

In total, 10 patients (8 men, 2 women; mean age=40.7 years, range, 29-52) were identified and reviewed in 2018 and 2019. All patients had received ultrasound diathermy therapy for symptoms of the shoulder (n=8, 80%), ankle (n=1, 10%) and wrist (n=1, 10%) [Table]. All the unusual bone lesions evident on MR were located at the site of diathermy treatment. The number of diathermy sessions before the MRI examination ranged from 3 to 7 sessions (mean, 5 sessions) [Table]. The time lag between diathermy and the MRI ranged from 1 to 24 weeks (mean=6 ± 7 weeks). All patients reported pain during diathermy, graded as mild in six (60%) patients and severe in four (40%) patients. These four patients with severe pain discontinued diathermy treatment due to pain.

A total of 12 bone lesions were present in the 10 patients (Figures 1-6). All bone lesions were subcortical and

Table. Patient and magnetic resonance details.

Patient	Sex/ age, y	Lesion site	No. of lesions	Lesion size, mm	Time between diathermy and magnetic resonance	No. of diathermy sessions	Pain level during diathermy
1	M/35	Shoulder, greater tuberosity	1	20 × 23 × 9 (MRI 1) 32 × 23 × 9 (MRI 2) 27 × 21 × 5 (MRI 3)	1 week (MRI 1) 6 weeks (MRI 2) 50 weeks (MRI 3)	3 before MRI 1 1 before MRI 2 1 before MRI 3	Mild
2	M/52	Shoulder, greater tuberosity	1	18 × 14 × 6	24 weeks	4	Mild
3	M/35	Shoulder, greater tuberosity	1	19 × 14 × 4	1 week	4	Severe
4	F/47	Shoulder, lesser tuberosity	1	19 × 9 × 4	4 weeks	7	Severe
5	M/30	Shoulder, greater tuberosity	1	11 × 15 × 2	2 weeks	2	Mild
6	M/39	Shoulder, greater tuberosity	1	7 × 11 × 5	12 weeks	6	Mild
7	M/47	Shoulder, greater tuberosity	1	28 × 12 × 7	4 weeks	7	Severe
8	F/46	Shoulder, greater tuberosity, lesser tuberosity	2	13 × 8 × 3, 19 × 20 × 2	4 weeks	6	Mild
9	M/47	Wrist, 1st metacarpal base	1	6 × 5 × 3	4 weeks	5	Mild
10	M/29	Ankle, distal tibia	2	26 × 20 × 5, 19 × 9 × 4	4 weeks	6	Severe

Abbreviation: MRI = magnetic resonance imaging.

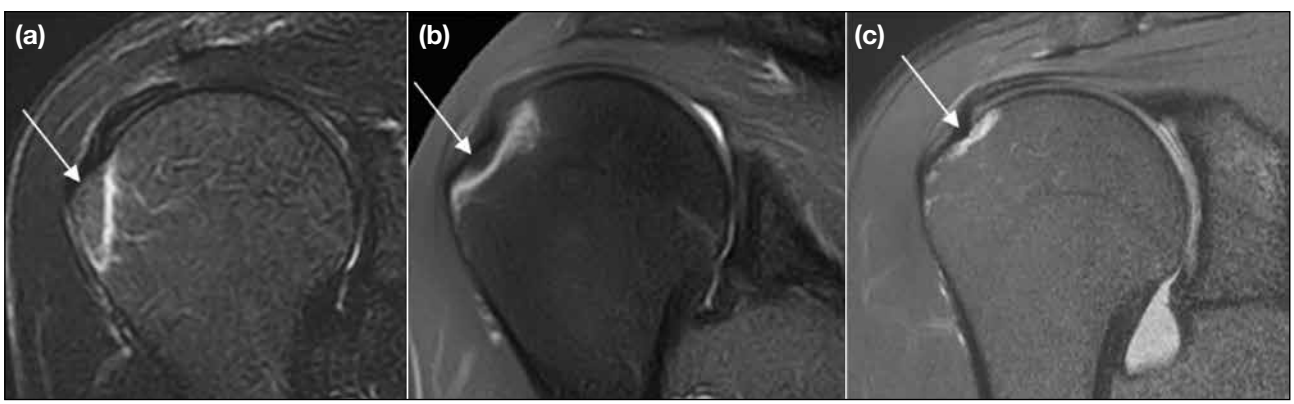

Figure 1. T2-weighed fat-suppressed coronal image from magnetic resonance imaging (MRI) examinations in (a) November 2017, (b) 1 month later and (c) 11 months later in a 35-year-old man (patient 1) showing a subcortical T2-hypertintense lesion of the greater tuberosity (arrows). The patient had had a diathermy session to this site 1 week prior to magnetic resonance examination. The lesion shows a bright rim around a central isointense area on the T2-weighted images of this initial MRI examination, compatible with necrotic bone, which gradually improved over the ensuing 12 months.

Figure 2. T2-weighed fat-suppressed coronal image of a 35-year-old man (patient 3) showing a subcortical T2-hypertintense lesion of the greater tuberosity (arrow) deep to the supraspinatus tendon insertion. The patient had had a diathermy session to this site 1 week prior to magnetic resonance imaging examination.

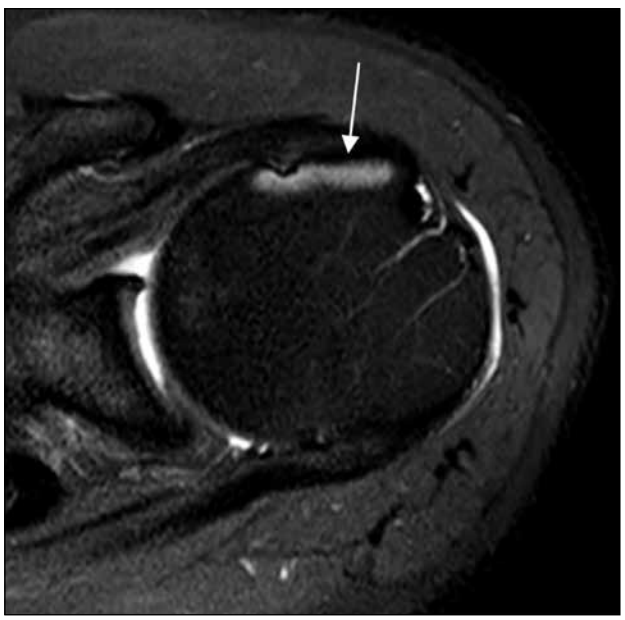

Figure 3. T2-weighted fat-suppressed axial magnetic resonance (MR) examination of a 47-year-old woman (patient 4) showing a subcortical oblong hyperintense lesion of the lesser tuberosity (arrow) deep to the subscapularis tendon insertion. Patient had received seven diathermy sessions to this location, the most recent of which was 4 weeks prior this MR examination.

at a relatively superficial location, i.e. with little soft tissue between the skin and the bone surface. All bone lesions had a rounded or oblong lesion shape with a thick

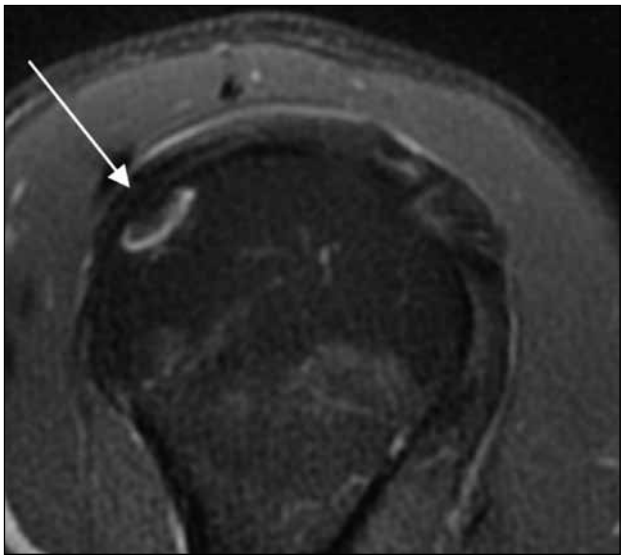

Figure 4. T2-weighted fat-suppressed sagittal magnetic resonance (MR) examination of a 39-year-old man (patient 6) showing a subcortical ovoid lesion of the greater tuberosity (arrow) with a hyperintense rim and a relatively isointense centre deep to the insertion of the infraspinatus tendon. The patient had undergone six diathermy sessions to this location, the most recent of which was 12 weeks prior to the MR examination.

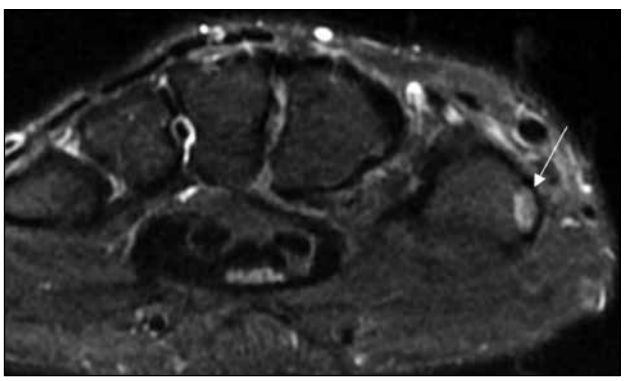

Figure 5. T2-weighted fat-suppressed axial magnetic resonance (MR) examination the wrist in a 47-year-old man (patient 9) showing a subcortical oblong-shaped lesion at the radial aspect of the base of the first metacarpal bone (arrow). The patient had undergone five diathermy sessions to this location, the most recent of which was 4 weeks prior to this MR examination.

hyperintense rim on T2-weighted images. A central isointense area was present in eight (67%) of the 12 lesions. No relationship between lesion volume (p=0.30) or lesion depth (p=0.43) and this central isointense area was found. There was no surrounding bone marrow oedema. The overlying cortex was intact without bone collapse or fracture and the overlying soft tissues were also unremarkable without oedema or inflammation.

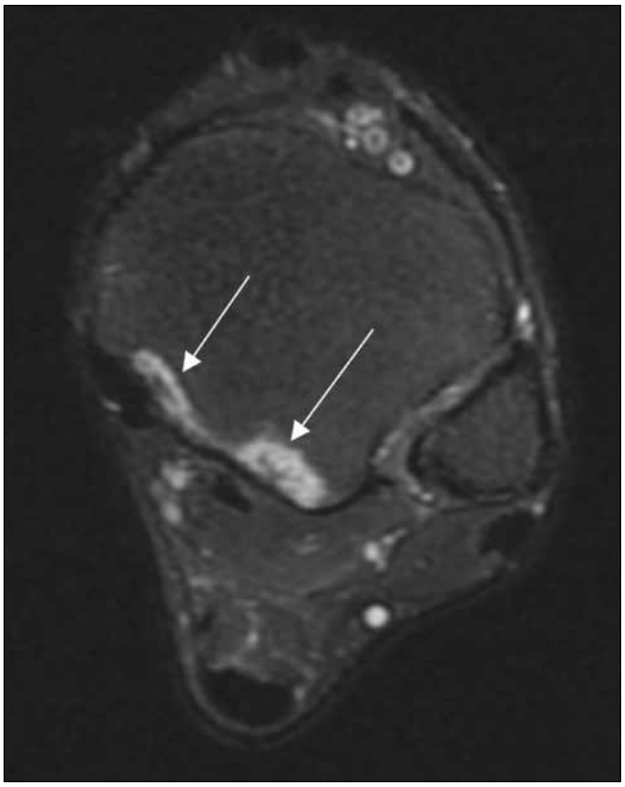

Figure 6. T2-weighted fat-suppressed axial magnetic resonance (MR) examination of the ankle in a 29-year-old man (patient 10) showing two subcortical oblong-shaped rim-like lesions at the posterior aspect of the distal tibia (arrows). Patient had six diathermy sessions at this location, the most recent of which was 4 weeks prior to this MR examination.

DISCUSSION

We present a series of patients with unusual bone lesions on MRI following diathermy treatment. All lesions were similar in appearance, being well-demarcated, subcortical in location, small- to medium-sized, located close to the skin surface, with a thick rim of hyperintense signal on T2-weighted images indicative of immature granulation tissue or inflammation with a central more isointense area indicative of osteonecrotic tissue.

All patients had received diathermy to the affected areas shortly before MRI examination. As no MRI prior to ultrasound diathermy was available, cause and effect were not established, though, a direct causation relationship was, nevertheless, very likely. A single previous report of eight patients demonstrating identical bone lesions in the shoulder, knee, and wrist following ultrasound diathermy treatment also considered these bone lesions to be iatrogenic.[9]

Although none of the bone lesions presented here or previously[9] underwent biopsy, the imaging appearances are compatible with subcortical osteonecrosis. Subcortical osteonecrosis typically has an oblong-shaped configuration with a hyperintense rim on T2-weighted images due to immature reparative granulation tissue and an isointense central area due to necrotic bone.[10] It has been found that if the osteonecrotic area is large, vascular compromise will limit repair to a degree that appreciable healing will not occur.[11] However, if the osteonecrotic area is small, the initial vascular compromise can be circumvented, provided the initial insult is discontinued, enabling small areas of osteonecrosis to heal over time with revascularisation and bone repair.[12] Such a healing response was apparent in the one case presented that underwent follow-up MRI and in three (38%) of the eight patients reported by Yeh et al.[9]

Therapeutic ultrasound can be low or high intensity. Low-intensity (0.03-3.0 Wcm^2) therapeutic ultrasound is used in ultrasound diathermy to treat soft tissue injury. Low-intensity pulsed ultrasound is used to accelerate fracture healing.[4,13] At the other end of the scale, high-intensity focused ultrasound (~1000 Wcm^2) uses a tightly focused ultrasound beam to treat tumours of the breast, prostate, liver, uterus, and bone.[5] Absorption of ultrasound energy leads to tissue heating. Diathermy aims to heat the soft tissues to increase local blood flow and promote tissue healing.[4,5] Any heating effect is highest at the skin surface and reduces with increasing depth due to ultrasound beam absorption and reflection.[14] As bone is a highly reflective interface, ultrasound energy absorption into bone is minimal. However, at very high energy levels, high-intensity focused ultrasound can induce bone osteonecrosis, by osteocyte damage and vascular thrombosis, with a direct relationship existing between ultrasound exposure duration, tissue temperature and bone damage for temperatures above 43°C.[11] Other than the patients presented here and the one previous report,[9] low-intensity ultrasound diathermy has not been recognised to cause bone changes. While the superficial location of the affected bone areas would have increased susceptibility to any ultrasound beam, the effect of specific technical parameters such as ultrasound duration, mode (continuous, long or short pulsed), beam intensity, and frequency is not known as these were not investigated in this study. Ultrasound diathermy treatment parameters were available in three (38%) of the eight patients previously reported and all of these were considered to be within the recommended treatment range.[9]

Ultrasound diathermy was performed for focal joint symptoms with radiographs and MRI being requested for persistent symptoms. As we did not specifically enquire whether symptoms deteriorated or changed following ultrasound diathermy treatment, we could not ascertain how, if at all, symptoms were directly attributable to the bone lesions. Small areas of osteonecrosis are often asymptomatic.[10,12] Focal symptoms did, however, improve in all previously reported patients for whom follow-up data were available.[9]

In conclusion, a series of patients with focal bone lesions following ultrasound diathermy treatment is presented. The aim of this presentation was to increase clinical awareness of these unusual bone lesions, which most likely represent areas of subcortical osteonecrosis. In the appropriate clinical context, no further investigation is necessary. Reports with follow-up of these lesions suggest they are reversible with no long-term sequelae.

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