MAGNETIC RESONANCE-GUIDED FOCUSED ULTRASOUND SURGERY FOR TREATMENT OF OSTEOID OSTEOMA: HOW DO WE DO IT?

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ABSTRACT
Magnetic Resonance-guided Focused Ultrasound Surgery (MRgFUS) is an increasingly popular non-invasive technique for treatment of severe pain produced by soft tissue, or bone tumours. MRgFUS utilizes targeted thermal ablation technique to control moderate to severe pain.
Osteoid osteoma is a small benign, highly vascular tumour, composed of osteoid and woven bone, most commonly affecting the appendicular skeleton. Bony spine involvement can produce painful scoliosis, while intra-articular joint involvement can cause irreversible joint damage. Clinical presentation is local bone pain which is typically worse at night and with increased activity.
Conventional standard treatment of osteoid osteoma is analgesics or surgical intervention. Under conservative medical treatment, the patient needs to be on long term analgesics, e.g. salicylates, where well-known reported complications include renal tubular acidosis and gastric ulcer. The standard surgical treatment is curettage. However, this carries the risk of bleeding, infection and tissue damage. Minimally invasive radiofrequency ablation (RFA) or cryoablation which are the current treatments of choice also carry the risk of tumour rupture and bleeding. We present a case of severe bone pain from a benign bone tumor (osteoid osteoma), successfully treated with noninvasive Magnetic MRGFUS.

Keywords: Osteoid osteoma, Magnetic Resonance Guided Focused Ultrasound Surgery, salicylates, radiofrequency ablation, cryoablation,

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1. INTRODUCTION

Osteoid osteoma is a small, benign, highly vascularized tumour, composed of osteoid and woven bone. Local bone pain is the chief complaint of patients with osteoid osteoma. The pain is often worse at night and with increasing physical activity. It is typically relieved by salicylates (75%) or any other non-steroidal anti-inflammatory drugs (NSAIDs) [1,2]. Osteoid osteoma is commonly encountered in the second to third decades of life with male to female ratio of 2-3:1 [1]. It can be found in any bone, but most commonly affects the appendicular skeleton. More than 50% occurs in the diaphysis and metaphysis of long bones, favoring the lower extremities. Majority is in the femur (65%) and the tibia (53%). Osteoid osteoma in the spine can cause severe back pain whereas intra-articular osteoma if left untreated can cause irreversible joint damage [1,2].

The standard conventional treatment includes medical treatment or surgical intervention. The patient needs to be on long-term analgesics, such as salicylates or NSAIDs if managed medically. Well-known commonly reported side effects of these compounds are renal tubular acidosis and gastric ulcer. More aggressive treatment options include surgical removal or excision which include RFA and cryoablation. These procedures carry risk of excessive bleeding, local tissue damage, tumour rupture and seeding [2,3]. MRgFUS is an increasingly popular non-invasive treatment for severe pain induced by soft tissue and bone tumours. MRgFUS utilizes a targeted thermal ablation technique to control moderate to severe pain [4].

We present a case of benign bone tumor (osteoid osteoma of the lower limb), successfully treated with non-invasive MRgFUS in a young female.

2. CASE REPORT

A 22-year-old female presented with insidious onset of pain and swelling at the antero-medial aspect of the right leg over an eight-year duration. The pain worsened at night, increased with physical activity and persisted at rest. No history of fever, weight loss or trauma. Patient's visual analogue scale for pain was 7 over 10.

On physical examination, there was a diffuse soft tissue swelling in the upper 1/3rd medial aspect of the right tibia, measuring approximately 8.0 x 7.0 cm. It was non-tender and non-fluctuant on palpation.

Plain antero-posterior (AP) and lateral radiographs of the right leg revealed cortical thickening, solid periosteal reaction and focal soft tissue swelling at the upper 1/3rd of the medial aspect of the right tibia. A small radiolucent subperiosteal nidus was present measuring 8mm in diameter.

The pre-procedure Magnetic Resonance Imaging (MRI) of the right lower limb performed on 1.5T GE system revealed a small nidus within the cortex at the middle 3rd of the shaft of tibia measuring 5.0mm. No cortical break demonstrated (Fig 1). MRI also showed a heterogeneously enhancing soft tissue mass measuring 3 x 2cm with irregularly thickened periosteum adjacent to the nidus (Fig 2).

Patient was treated with MRgFUS using ExAblate 2000 device that was integrated with a MRI scanner (GE 1.5T) that allows precise targeting and ablation of tissue or bone without the need for open surgical procedure. The procedure was performed under sedation and analgesia with intravenous midazolam and pethidine. Based on the pre-treatment MRI and CT images, the target (bone lesion) was identified and positioned on a water bath containing an ultrasound transducer that had been coupled with a gel pad. Images were then transferred onto the MRgFUS work station. The targeted area was specifically delineated to avoid damage to the surrounding tissue whilst optimizing the energy level. A total of 31 sonications were delivered to the target.

Patient was discharged home the next day. Prior to discharge, the patient's visual analogue scale for pain had reduced to 2/10 from the previous 7/10. Patient was subsequently followed-up in the orthopedic clinic. At six-month follow-up, the visual analogue scale for pain was 3/10 without the patient requiring any form of oral analgesics. Clinically, there was marked reduction in the size of the soft tissue swelling which corresponded to minimal bone marrow and soft tissue oedema, and reduction in the size of nidus (from 5mm to 1.5mm in diameter) on the follow-up MRI (Fig 3).

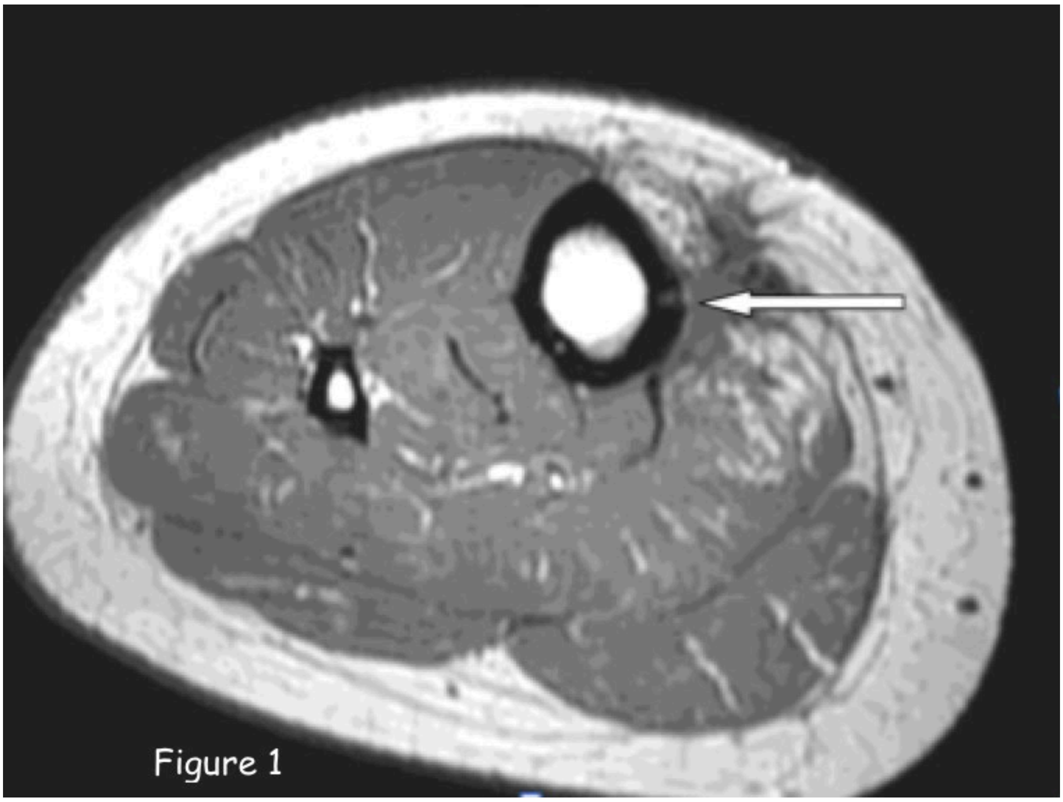

Figure 1: Pre-treatment post gadolinium axial T1 demonstrates a small nidus (arrow) within the cortex at the middle 3rd of the shaft of the tibia measuring 5.0mm.

Figure 2: Pre-treatment post-gadolinium coronal T2FS shows irregularly thickened periosteum with adjacent enhancing soft tissue swelling suggestive of soft tissue oedema. No cortical break noted.

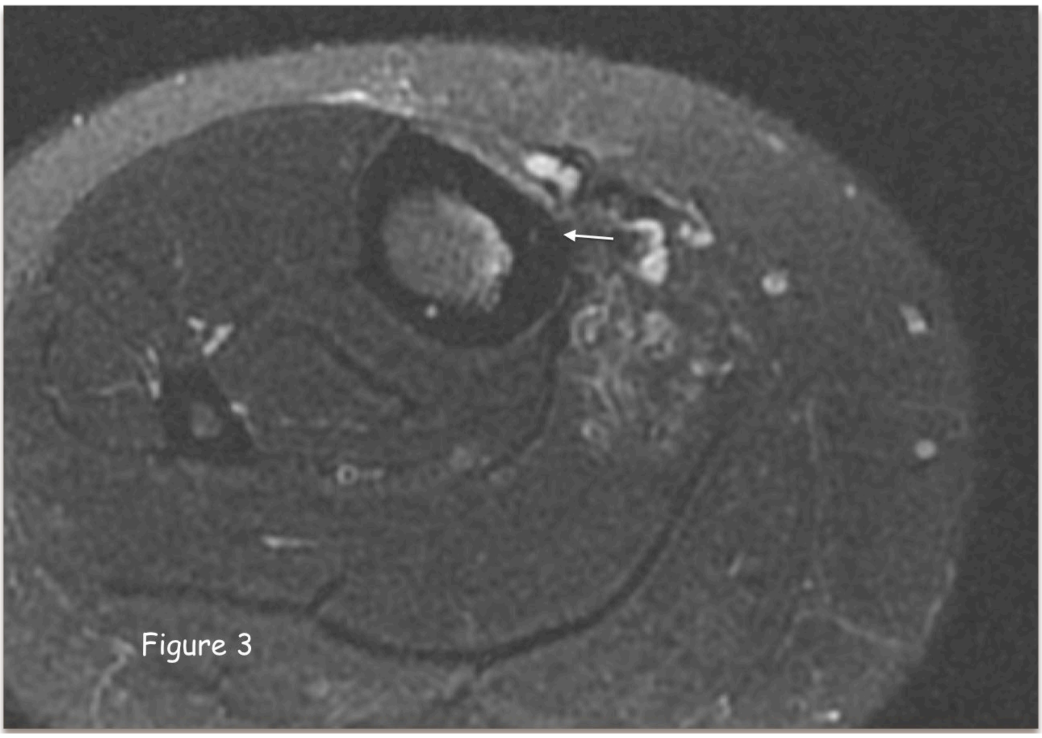

Figure 3: Post-treatment Axial T2 FS image demonstrating smaller nidus now measuring 1.5mm.

3. DISCUSSION

Osteoid osteoma represents 4% of primary bone tumors and 12% of benign bone tumors. Presence of radiolucent nidus (less than 1cm in greatest diameter) surrounded by sclerosis, is compulsory in imaging for diagnosing osteoid osteoma. The nidus is made up of osteoid or mineralized, immature, woven bone surrounded by highly vascular, fibrous stroma with osteoblastic and osteoclastic activity. It is believed that prostaglandin E2 is 100 to 1000 times higher within the nidus, which is likely the cause of pain and vasodilatation [1,2].

Surgical treatment is invasive and cosmetically disfiguring as the surgeon may need to excise a significant piece of bone to ensure that the lesion is completely removed. Due to the small size, it may be difficult to identify and locate the lesion intraoperatively. Thus, internal fixation or bone grafting may be required. In recent years, percutaneous nidus excision via CT guided nidus drilling, ethanol injection, RFA and laser-induced interstitial thermotherapy (LITT) have been established [3]. These methods showed better outcome compared to conventional surgery however, there are still issues with complications due invasive nature of these procedures [2,6].

High-Intensity Focused Ultrasound (HIFU) is a highly precise non-invasive thermal ablation technique that uses high-intensity focused ultrasound energy to create heat and destroy the pathogenic tissues within the body [5]. When coupled with MRI for guidance, the technique is called MRgFUS. Recent studies carried out in several centers worldwide demonstrated that HIFU is clinically useful in treating solid benign and malignant tumours which include uterine fibroid, adenomyosis, renal tumor, primary/secondary bone tumor, primary/secondary liver tumor, breast, brain and prostate cancer [1,3,6]. Lieberman B et al showed that thermal ablation technique has the ability to provide accurate, effective, non-invasive and safe treatment of bone pain, for patients with bone metastases [3].

An extensive study by Catane R, et al., [1] showed that MRgFUS provide safe, effective and non-invasive alternative treatment of bone pain. It also showed that the main complications of MRgFUS in treating malignant bone tumor are skin burns and local nerve injury. No other serious adverse effect has been reported. In MRgFUS, the radiologist can accurately localize the target lesion on MRI and optimally direct and deposit significant amount of acoustic energy (sonication) to the targeted tissue whilst monitoring energy deposition. Thermal deposition dose can be accurately calculated in each sonication using MR thermometry in real time. The amount of damaged tissue can also be modelled by Cumulative Equivalent Minutes (CEM) equation [6,7]. The directed HIFU beam is harmless to the skin and intervening tissues as it only focuses on the three-dimensional target. The acoustic wave can also be focused at more than one area and the entire volume can be thermally ablated. The target lesion will undergo coagulative necrosis when approximately 65° to 100°C temperature is delivered between 0.5 to 1.0 seconds [7]. Little damage occurs to the surrounding healthy tissues. This precise ablation technique is one the main advantages of HIFU treatment. Others~~,~~ include low cost, non requirement of general anesthesia or prolonged hospitalization [8].

To date, we are the first centre in Malaysia which uses MRgFUS to successfully treat bone pain from benign bone tumour in-particular, osteoid osteoma. More importantly, patients experience significant pain improvement with an average VAS score reduction from 7.0 to 3.0 at 6-month post treatment.

4. CONCLUSION

MRgFUS is a new promising technology which is safe, accurate, effective and non-invasive and has a potential to become an alternative treatment for bone pain caused by osteoid osteoma in Malaysia.

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