



Computed Tomography-Guided Percutaneous Radiofrequency Ablation of Osteoid Osteomas: Joining Forces of Orthopedic Oncologists and Radiologists

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Abstract

Osteoid osteoma (OO) is a painful nonaggressive bone tumor, which presents a therapeutic challenge in providing pain relief using the least invasive approach. Radiofrequency ablation (RFA) is a minimally invasive method with increasing importance in OO treatment. Although surgeons in some centers still prefer operative management of the tumor, a team with oncologic orthopedists and radiologists working together offers reduced morbidity by using a safe and effective method of treatment with computed tomography-guided RFA.

Keywords: Osteoid osteoma; Radiofrequency; Ablation

Abbreviations: RFA: Radio Frequency Ablation; OO: Osteoid Osteoma; CT: Computed Tomography

Introduction

Minimally invasive strategies in image-guided tumor ablation are gaining increasing attention as viable therapeutic options for musculoskeletal tumors [1,2]. Since the first description in 1992 [3], many authors have demonstrated the safety and effectiveness of radiofrequency ablation (RFA) [4-6], but the technique is not yet widespread in orthopedic oncologic centers around the world. The unaffordability of the required equipment in some places and difficulty in obtaining a biopsy specimen to confirm diagnosis are obstacles for many surgeons. In our experience, a team approach with orthopedic oncologists and interventional radiologists can make the RFA procedure more patient-tailored.

Owing to the refinement of imaging modalities and the RFA technology, resulting in less bone fragility, this method overcomes two challenges of the operative treatment: first, the need for reconstruction of larger bone defects, which introduces significant morbidity, and second, incomplete resection resulting from the difficulty in localizing the nidus intraoperatively, which may result in high rates of local recurrence [7].

Osteoid Osteoma: Clinical and Imaging Features

Osteoid osteoma (OO) is a painful benign bone-forming tumor, first described by Jaffe in 1935, which represents 10% of benign bone tumors, with a peak incidence in the second decade of life [8,9]. Rarely, lesions have been observed in patients as young as 5 years, and at least 50% of these tumors occur in the long bones of the lower extremities [9].

Although OO is usually a nonaggressive lesion, it often results in a characteristic pain pattern. Patients frequently complain of a dull ache for months before the diagnosis. Intense non-mechanical pain that is disproportionate to the size of the lesion, present at rest and night, and rapidly alleviated temporarily by the administration of non-steroidal anti-inflammatory drugs (NSAIDs) leads to the clinical suspicion [10]. Two concomitant mechanisms are involved in the pain pathogenesis. The well-documented production of prostaglandin E₂ by the tumor

cells resulting in inflammation, pain, and vasodilatation explains the pain relief by inhibition of the prostaglandins production with NSAIDs [11-13]. The presence of free unmyelinated sensory nerve endings in the nidus stimulated by the marked vascularity is the second pain-related factor [14].

The radiographic appearance of the OO is also characteristic. On plain films, a small oval central lytic lesion (nidus), usually less than 15 mm diameter with a variable quantity of calcification, surrounded by a sclerotic rim and adjacent cortical thickening is highly suggestive of the diagnosis [15] (Figures 1A-1C). The nidus can be located in cortical or medullary bone, most frequently at the periosteal or endosteal surfaces. In the cortex, occasionally, the very sclerotic reactive bone obscures the nidus on the plain film, but it is accurately demonstrated in high-resolution computed tomography (CT) imaging, which is also essential for planning the percutaneous approach to the lesion. Conventional magnetic resonance imaging (MRI), when used as the only imaging method for OO evaluation, may lead to misdiagnosis because of the soft-tissue and medullary edema [16] (Figures 1D and 1E). Therefore, MRI has been reported to be of limited value compared with CT in demonstrating the nidus [17-20]. However, to enhance diagnostic accuracy, we routinely use advanced MRI techniques, especially dynamic contrast-enhanced MRI with color mapping and in-phase/opposed-phase sequences, to identify the nidus and to differentiate these tumors from other conditions such as infection (Brodie abscess), inflammatory arthritis, and other tumors (Figure 1F). Most OOs show

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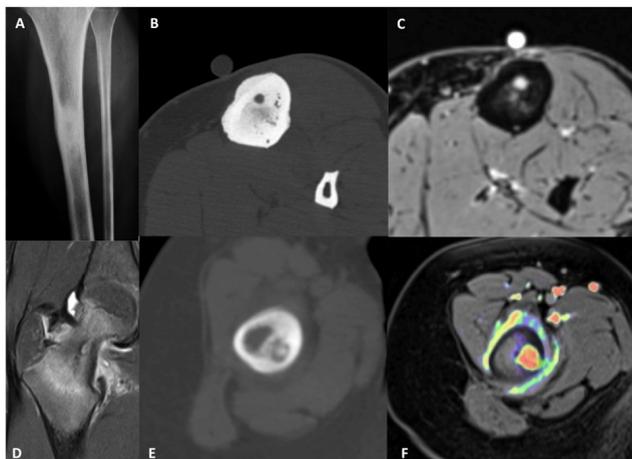


Figure 1: (A) Characteristic radiographic appearance of circular lucency representing the nidus surrounded by sclerosis is seen in the middle third of the tibia. (B) Axial computed tomography (CT) scan demonstrating clearly the location of the nidus in relation to the cortical bone and the dense periosteal reaction. (C) Axial view of magnetic resonance (MR) T1-weighted sequence with fat suppression demonstrating the hyperintense signal obtained with gadolinium of the hypervascular nidus during the arterial phase. (D) Coronal view of MR proton-density sequence with fat suppression demonstrates the bone edema surrounding the nidus at the femoral neck, which can help to find the nidus without much reactive sclerosis. (E) Axial view of CT scan shows a calcified nidus in a subcortical location. (F) Axial dynamic MR demonstrates the intense vascularization within the nidus.

arterial-phase enhancement and rapid partial washout as a result of hypervascularity of the nidus [20].

Treatment may be instituted if clinical and imaging features are typical even before histopathological confirmation. Because OOs have limited growth and no malignant potential, treatment may be performed with intralesional margins. Some lesions have been reported to resolve spontaneously over time [21], and a surgical approach is needed only when significant pain impairs normal living. RFA is an effective way to eliminate pain by destroying the nidus with less operative and bone injury.

RFA Mechanism of Action

The RFA mechanism of action is thermal cell damage and coagulation necrosis induced by the elevated temperatures obtained with the high-frequency electromagnetic energy (approximately 500 kHz) [22-24]. The electrode inserted into the tumor sends a type of alternating current (radiofrequency) that causes local ionic agitation, creating friction that, in turn, generates heat and consequently thermal cell damage and coagulation necrosis [4,22-24]. The basis for irreparable cell damage centers on disruption of the cell membrane and protein coagulation of cytosolic and mitochondrial enzymes and nucleic acid-histone protein complexes [24].

Radiofrequency OO ablation therapy, by inducing thermal tissue injury, attempts to completely eradicate all viable tumor cells within a designated area in a minimally invasive manner, limiting injury to nearby structures [25]. The extension of RFA-induced lesions is determined by the size of the active electrode tip, duration of current, tissue type, and temperature. Irreversible cellular injury occurs when cells are heated to 46°C (114.8°F) for 60 min and occurs more rapidly as the temperature rises [26]. Otherwise, temperatures of >100°C (212°F) have been found to cause boiling and vaporization of the surrounding tissue, resulting in the formation of a coagulum and increased

impedance to further current, thereby limiting the effective zone of treatment [27].

The RFA Procedure

We perform the intervention in a CT room with local and general anesthesia because of the severe pain associated with drilling the sclerotic bone. The RFA procedure is shown in Figure 2. A localizing scan using collimation of 2 mm is performed to locate the nidus and the best skin entry point. A rotatory battery-powered bone biopsy device is inserted percutaneously to penetrate the cortical bone [28,29]. A bone biopsy specimen is obtained and the track is used as an access for the electrode [30,31]. A standard single electrode with a 10 to 12 mm exposed tip is used. The recommended distance between the electrode and vital structures (e.g. vessels and nerves) is 1 cm to avoid injury. Hydrodissection or pneumo-dissection techniques should be considered to prevent these complications [6-32]. The generator is turned on and the electrode is activated until a temperature of approximately 90°C (194°F) is reached and sustained for 6 min [33]. Depending on the RFA system used, the necrosis area obtained, and the lesion size, the electrode can be repositioned and additional cycles performed to ensure adequate coverage of the lesion. According to the level of pain, full weight-bearing is immediately allowed after the procedure and hospital discharge occurs on the same day with oral analgesia [3,34].

Therapeutic Outcomes

Several clinical studies have reported high success rates for RFA treatment of OO associated with a low risk of complications and recurrence rates similar to those of standard surgical management [5,6,35,36]. Pain relief is the most reliable success predictor. The cure rate has been reported as ranging from 75% to 100% [37-40]. Recurrence rate is smaller than 15% and it is associated with larger lesions, younger age, and with the need for multiple needle positions during the procedure [39]. However, even if recurrence occurs, retreatment with RFA has been successful [6]. Although it occurs rarely, the most significant complication consists of local skin burns, which may occur when the active electrode tip is close to the cutaneous surface or in direct contact with the guiding cannulas [6]. For this reason, we prefer to insert the electrode without cannulas to guide it through the hole created by the drill. However, some authors have

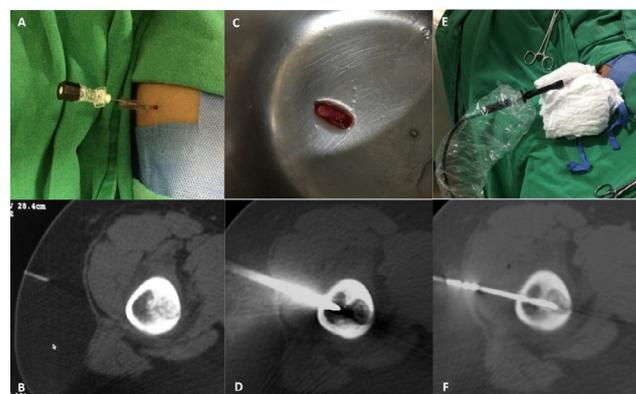


Figure 2: Ablation procedure. (A/B) The osteoid osteoma nidus located in cancellous bone is identified on the computed tomography (CT) scan, and a skin entry point is selected. (C/D) Percutaneous biopsy for preparing electrode access to the lesion. (E/F) Axial CT scan showing the electrode introduced into the nidus.

mentioned that RFA can safely be done through vertebroplasty or biopsy cannulas [34]. Complications other than skin burns, including necrosis of adjacent structures (e.g. nerves, vessels) and fracture, are infrequent if the approach is well planned. Skin injury resulting in a subcutaneous fistula requires surgical treatment [34].

Conclusion

Success rates with RFA are similar to those with standard surgical curettage, but RFA results in decreased morbidity. The most significant advantage of this method is the potential minimal amount of normal tissue loss, resulting in a shorter recovery period, immediate pain relief and a faster return to daily activities. The procedure performed on an outpatient basis is effective, relatively safe and well-tolerated by the patient.

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