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TECHNICAL REPORT

Air-blocking ablation of osteoid osteoma; a technical note

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Abstract Osteoid osteoma accounts for approximately 10–12% of all benign bone tumors. Surgery was the treatment of choice for osteoid osteomas until percutaneous radiofrequency ablation (RFA) was introduced in 1992. Although RFA is generally considered curative in the treatment of osteoid osteoma, disease recurrence after ablation has been reported. We report a case in which RFA was delayed by the presence air surrounding the ablation probe. In this case, ablation could only be performed after the probe was removed and saline was injected through the introducer needle to displace the air. Air is reported to decrease radiofrequency energy transmission; a simple measure like injecting saline through an introducer could prevent such a complication. We also suggest that partial air in the ablation bed surrounding the ablation probe could decrease the energy transmission and may be one of the causes of early recurrences. Saline injection could be helpful in providing a more reliable environment for ablation.

Keywords Osteoid · osteoma · Ablation · Air · Complication

Abbreviations

OO	Osteoid osteoma
PTA	Percutaneous thermal ablation
NSAIDs	Non-steoridal anti-inflammatory drugs
RFA	Radiofrequency ablation
RF	Radiofrequency

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Introduction

Osteoid osteoma accounts for 10% of all benign bone tumors and is the most common benign bone tumor in young patients [1]. Various treatment options have been described for osteoid osteoma, however, computed tomography (CT)-guided radiofrequency ablation (RFA) is the most common technique and has been accepted as the gold standard of treatment since the early 1990s [2]. CT-guided RFA has demonstrated treatment rates similar to or better than other treatment modalities; in addition, RFA offers several advantages over surgery, including low invasiveness of percutaneous versus open access, minimal postinterventional observation, ability to treat high-risk localizations (e.g., intra-articular and spinal localizations), and lower cost [3–5]. Nearly all previous studies of RFA for the treatment of osteoid osteoma have reported very high technical success rates ranging between 94 and 100%; however, 5–24% of the patients in these studies experienced disease recurrence, demonstrating a discrepancy between clinical and technical success rates [6–8]. A recent meta-analysis reviewing 27 studies of CT-guided RFA treatment highlighted this wide variation, with an overall disease recurrence rate of approximately 5%; however, the authors could not identify any specific causes to explain these recurrences [3]. We report a case of RFA treatment of osteoid osteoma that was delayed by procedure-related air surrounding the ablation probe, resulting in high impedance levels that led to the RF generator shutting off. Although several risk factors have been reported in the literature for recurrence of osteoid osteoma, we believe air bubbles surrounding the probe caused by either biopsy or insertion of the ablation probe may prevent uniform energy transmission and could also contribute to some of the recurrences as suggested by this case report.

Case report

A 16-year-old girl presented with left shin pain that had gradually been increasing over the previous 3 months. The pain, which was worse at night and frequently caused nighttime awakenings, responded well to treatment with nonsteroidal anti-inflammatory drugs. A radiograph of the leg showed areas of cortical thickening with central luceny at the midshaft of the left tibia. Based on this radiograph and the patient's symptoms, a diagnosis of osteoid osteoma was established. Because pain was interfering with the patient's quality of life, percutaneous RFA was chosen for treatment. General anesthesia was administered, and the patient was placed in the prone position on the CT table. Pre-biopsy CT showed the nidus was surrounded by thick sclerotic reactive bone (Fig. 1), confirming the diagnosis. Two grounding pads were placed on the posterior thighs and connected to an RF generator (Medtronic/Covidien, Plymouth, MN, USA). Once the skin was prepared and draped with sterile technique, the lesion was biopsied with a 10-cm 12-gauge Bonopty needle (Radi Medical System, Uppsala, Sweden) under CT imaging guidance. After we obtained a single core biopsy, a 17-gauge 5.67-in. (14.4-cm) straight rigid cool-tip RF electrode (exposure, 0.7 cm; Medtronic/Covidien) was inserted coaxially (Fig. 2). We observed very high impedance values (>1000 Ω) after the initiation of ablation, which led to the RF generator shutting down. After unsuccessfully attempting ablation two more times, we decided to change the ablation probe in case of possible malfunction. Very high impedance values remained, and the ablation could not take place. We reviewed our checklist and changed grounding pads as the next step; we then obtained another RF generator when very high impedance values remained. None of these steps helped, and ablation could not be performed. During discussions among team members, the possibility of air around the tip of the ablation probe was raised. When the probe was pulled out of the biopsy cavity, a small pocket of air was visualized (Fig. 3); this was not visible when the probe was imaged inside the biopsy cavity. We immediately removed the ablation probe and injected

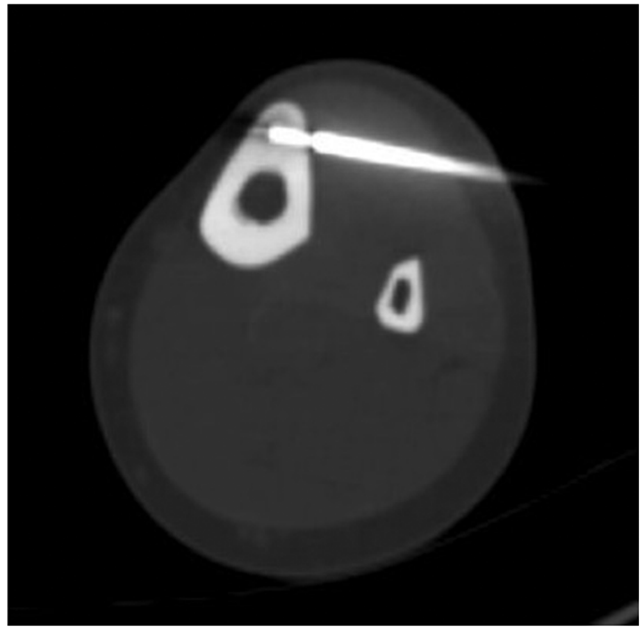

Fig. 2 Axial CT image showing the ablation probe within the nidus

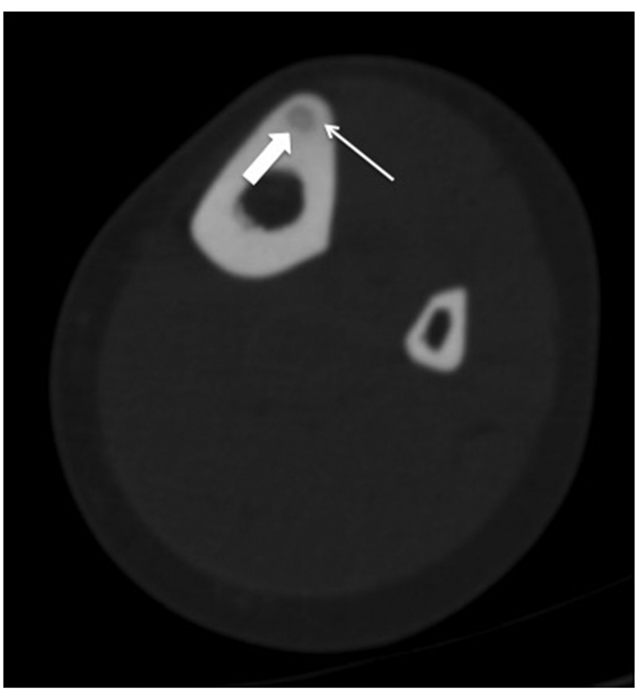

Fig. 1 Axial CT image showing osteoid osteoma nidus as central luceny (*thick arrow*) surrounded by a significant cortical thickening (*thin arrow*)

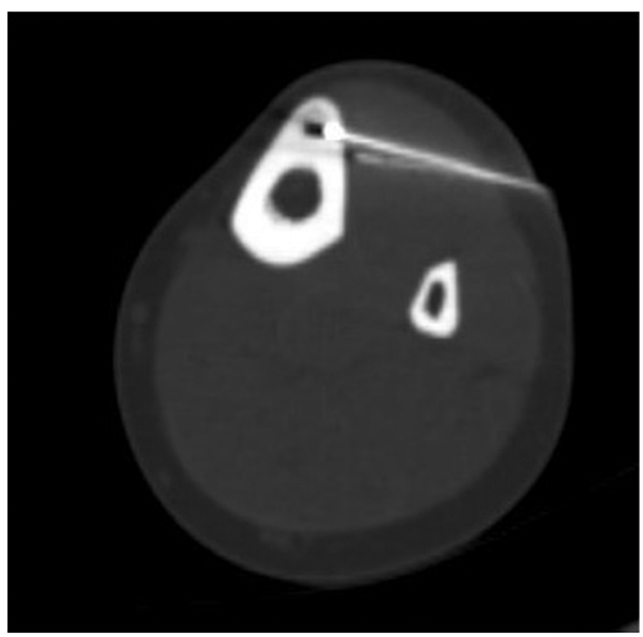

Fig. 3 Axial CT shows air filling the tract after the removal of the probe, blocking the RF energy transmission and ablation

saline through the introducer needle, pushing the air pocket out. Impedance readings after saline injection and air dislodgement decreased to an expected range of 200 to 300 Ω, allowing a successful ablation for 6 min at 90–95 °C. The patient was pain free at 3 months and returned to baseline activity. At a 6-month follow-up visit, the patient reported that the pain was completely resolved, and there were no signs of disease recurrence.

Discussion

RFA has largely replaced surgical excision of the nidus as the treatment of choice in symptomatic osteoid osteoma due to increased risk of instability, infection, spinal cord, nerve root, or vertebral artery damage and necessity of hardware placement in latter [9, 10]. The introduction of percutaneous RFA radically changed the treatment strategy for these lesions. The effectiveness of RFA for osteoid osteomas localized in the extremities and pelvis has been demonstrated in many studies [5, 11]. Although researchers have explored treatment with new minimally invasive techniques and other percutaneous treatment options such as CT-guided excision with trephines and needles, cryoablation, and laser photocoagulation [12, 13], percutaneous RFA is still the most commonly used technique because of its demonstrated safety and efficacy. Percutaneous RFA has a very high technical success rate ranging between 94 and 100% for the treatment of osteoid osteoma [5, 8], but some patients have only a partial clinical response, and it is generally understood that a small percentage of patients treated with RFA will have a symptomatic recurrence even after several pain-free months no matter how technically successful the procedure was [3].

The exact cause of osteoid osteoma recurrence after RFA remains unclear. Long-term regrowth after therapy, errors in differential diagnosis, and inadequate treatment of large osteoid osteomas have been suggested as possible causes [14, 15]. Incomplete RFA of large osteoid osteomas is a well-known cause of recurrence [14]. Some studies have also demonstrated that after complete RFA, there is no significant difference in the recurrence rate of large and small osteoid osteomas [14, 16]. Most postablation recurrences occur within 3–6 months after the procedure [17]; after 6 months, the frequency of recurrence decreases. Some authors have suggested that most early recurrences could represent cases of inadequate treatment with residual osteoid osteoma rather than true recurrences [15]. Recurrence after 2 years, however, is extremely rare [3]. These findings suggest that there are undescribed causes for early recurrences.

Air is a well-known insulator of radiofrequency energy transmission to tissues [18]. Several studies have reported exploitation of air during treatment of spinal osteoid osteoma, air served as an insulating material thereby protecting the neural elements from damage due to the RFA [19–21]. Thermal conductivity of air is 23.94 mW/mK [20]. Efficacy of epidural injection of air through spinal needles placed under CT guidance was shown by Rybak et al. in a retrospective, multicenter analysis successfully preventing thermal damage to the neural structures [21]. Air is a good insulator with high impedance, defined as the electrical resistance to current flow in a tissue, but it was reported to cause embolism because of lower solubility [19, 22]. Several authors have described air injection by means of a 22-gauge spinal needle for the insulation of vulnerable structures from the ablation zone [19, 22]. CO_2 is suggested to be a better insulator than air with lower thermal conductivity of 14.65 mW/mK at 0 °C [18].

In our case, air completely surrounding the probe did not allow us to begin the ablation procedure. Several studies have reported using air as an insulating material during RFA treatment osteoid osteoma, protecting the surrounding tissues from damage [19, 20, 22, 23]. If the ablation probe is partially covered by air, some sections of the osteoid osteoma nidus may not be treated, as RF energy flows into areas where less resistance is present. We typically create a bony biopsy track 1 to 2 mm longer than length of the active tip to ensure RF energy distributed inside to bone rather than to the overlying soft tissue during RFA. If the active tip of the RF probe is not fully inside the bone, most of the RF energy will be drawn to overlying soft tissues, limiting bony ablation with a similar mechanism [15]. Introduction of air into the biopsy cavity is difficult to avoid, but in most cases, a small amount of procedure-related bleeding displaces the air. In this case, a markedly thickened cortex surrounding the nidus and a short biopsy tract in the bone may have contributed to the lack of bleeding. Although air in our case could be introduced during the insertion of a biopsy needle or initial or second RF ablation probe as first RFA cycle failed and RF probe was inserted coaxially we think that most probable scenario in this case is air was introduced during biopsy. Based on this experience, we speculate that some cases of early disease recurrence after RFA may be caused by air partially surrounding the probe during the procedure, leading to incomplete ablation. If there is even minimal amount of air within the biopsy tract during CT imaging of osteoid osteoma ablation, saline injection should be considered to allow for a more homogenous distribution of RF energy.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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