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SCIENTIFIC ARTICLE

Therapeutic outcome of CT-guided radiofrequency ablation in patients with osteoid osteoma

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Abstract
Objective To assess the long-term outcome of computed tomography-guided radiofrequency ablation (CT-guided RFA) in patients with suspected osteoid osteoma (OO).
Materials and methods Single-center retrospective study. Patients with clinical suspicion and imaging diagnosis of osteoid osteoma were treated by CT-guided RFA using the same device with either a 7- or 10-mm active tip electrode. Specific precautions were applied in case of articular or spinal OO. Patients were contacted by phone to evaluate the long-term outcome in terms of pain, ability to perform daily activities (including sports), and long-term complications. Success was defined as the absence of residual pain and ability to perform daily activities normally.
Results From 2008 to 2015, 126 patients were treated by CT-guided RFA for OO in our institution. Mean patient age was 26.1 years (SD = 11, range 1–53); mean delay to diagnosis was 16.9 months (SD = 15.2, range 1–120). Among patients who answered the follow-up call (n = 88), the overall success rate was 94.3%: 79/88 (89.8%) had primary success of the procedure, and 4/88 (4.5%) had a secondary success (repeat-RFA after pain recurrence). Mean follow-up time was 34.6 months (SD = 24.7, range 3–90). Few complications occurred: two mild reversible peripheral nerve injuries, one brachial plexus neuropathy, one broken electrode tip fragment, and one muscular hematoma.
Conclusion Osteoid osteoma can be effectively and safely treated by CT-guided RFA using the presented ablation protocol. Beneficial effects of the treatment persist at long-term follow-up.

Keywords Radiofrequency ablation · Osteoid osteoma · Computerized tomography

Introduction

Osteoid osteoma (OO) is a benign bone tumor that most frequently affects young men under the age of 40 [1], causing chronic inflammatory pain increasing at night. It can occur at any location; however, there is a strong predilection for the femoral and tibial diaphysis [2]. Minimally invasive percutaneous procedures, including radiofrequency ablation (RFA), have become the standard of care. The RFA technique was first described in 1992 by Rosenthal [3]. Clinical series in the following years reported success rates close to 100% as well as other advantages of the technique such as minimal invasiveness, lower cost, and possibility to treat intra-articular lesions. However, some patients may experience an incomplete ablation or pain recurrence after several symptom-free months, leading to repeated RFA or surgery. Therefore, additional information is needed about long-term follow-up. We report the long-term outcome of a retrospective cohort of 126 patients with osteoid osteoma (OO) treated

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by CT-guided radiofrequency ablation (RFA) in one center from 2008 to 2015.

Materials and methods

From 2008 to 2015, all patients treated by RFA in our academic MSK center were included. The study protocol was approved by the local ethics committee.

Procedure data

Patients were informed about the RFA procedure, as well as alternative surgical and medical treatments, and gave informed consent to the RFA, as well as the follow-up call. All procedures were performed under MDCT guidance by five musculoskeletal radiologists (3 MSK radiology fellows with 2 years of experience in interventional MSK radiology and 2 MSK senior staff radiologists with 12 and 22 years of experience). All patients had a dedicated anesthesia consultation prior to the procedure, where the level of anesthesia was decided by the anesthesiologist and the patient, taking into account the location of the OO as well as specific skills of the anesthesiologist (for conscious sedation). Procedures were then performed under general anesthesia, locoregional anesthesia by nerve block in peripheral OO (below the femoral head or below the shoulder), or conscious sedation.

The approach was planned on MDCT limited to the area of interest. No CT fluoroscopy was used to perform the procedures. After strict asepsis and adequate grounding, access to the lesion was gained using either a 14-gauge or, from October 2014, a 12-gauge coaxial drill system (Bonopty Penetration Set; Apriomed Medical Systems, Uppsala, Sweden). After control of the accurate position of the drill system, the internal drill was removed and, whenever possible, a core biopsy was performed with a 15-gauge (18-gauge core sample size) needle (Bonopty Biopsy Set; Apriomed Medical Systems, Uppsala, Sweden). The biopsy needle was then replaced by the RF electrode. A 17-gauge RF cannula with a straight cooled tip of 7 mm (smallest available size for the device used in our study) or 10 mm (Cool-tip RF Electrodes; Covidien, Boulder, CO, USA) was used in all cases (Fig. 1). After control of the accurate position of the electrode tip, the electrode was connected to the RF generator (Cool-tip RF Ablation System E series, Covidien, Boulder, CO, USA). The procedures were then carried out by gradually increasing the electrode tip temperature to 85 °C and maintaining it for 5 min under continuous temperature monitoring at the site of ablation, displayed by the RF generator. Specific precautions were taken in case of articular (insulation by intra-articular injection of a 5% dextrose solution) or spinal lesions (epidural temperature probe placed during the procedure to allow continuous temperature monitoring and epidural insulation). A post-procedural MDCT was always performed to check for possible soft tissue damage.

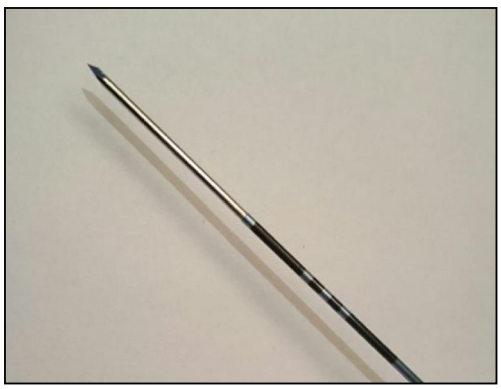


Fig. 1 RF electrode used in our center: 17-gauge RF cannula with a straight cooled tip of 7 or 10 mm (Cool-tip RF Electrodes; Covidien, Boulder, CO, USA)

Imaging data

Diagnosis of OO was a combination of clinical symptoms (inflammatory pain, increasing at night) with compatible cross-sectional imaging data (CT ± MRI). Relief with non-steroidal anti-inflammatory drugs (NSAIDS) was not considered mandatory. Unenhanced MDCTs were performed on a 16-detector row (Somatom Sensation 16; Siemens Medical Solutions, Erlangen, Germany) unit, applying parameters adapted to the lesion's location and the age of the patient (0.75–3-mm section width, bone reconstruction algorithm, 100–120 kVp and 100–300 mAs). MDCT was considered suggestive of OO when a round or ovoid lesion, with a maximum diameter of 2 cm, exhibited a nidus, well-defined margins, and variable surrounding osteosclerosis. Central calcification and periosteal reactions were not considered mandatory, as some OO cases do not show these signs. When MRI was available for review, medullary edema and nidus uptake were observed.

Preoperative imaging was reviewed to assess the nidus size, location of the lesion, and size of the nidus calcification if present. Per-procedure images were reviewed to assess needle targeting: whether the needle was located inside the lesion (transfixing) and whether the needle reached the center of the lesion (centered).

Outcome evaluation

From February 2015 to July 2016, patients were contacted by phone to evaluate long-term outcome. A structured interview was performed to retrospectively evaluate the

delay to diagnosis from symptom onset, pain before the procedure, and its evolution at several time points afterwards (1 day, 1 week, 1 month, 6 months, time to recurrence in failure patients, and present time) using a 10-point numeric scale, long-term complications, and the ability to perform daily activities (including sports) normally. Success of the treatment was defined as the absence of OO-related pain and the ability to perform daily activities normally. Success was either primary (success of the initial procedure) or secondary (success of the treatment after a repeated RFA). Failure was defined as either persistence or recurrence of the pain or the necessity of surgical treatment. Early postoperative pain was defined as a numeric scale (NS) above 5/10 at the day 1 evaluation.

Statistical methods

Statistical analysis was performed using SPSS 20.0 software.

Quantitative variables were presented using the mean value or standard deviation or median and interquartile range, and qualitative variables were expressed as percentages. Continuous and categoric variables were compared by using Student's t-test (or Mann-Whitney) and chi-square (or Fischer) tests, respectively. Due to the small number of treatment failures, the use of a multivariate logistic regression model to identify risk factors for treatment failure was not possible.

Table 1 Patients characteristics

Variable	Mean (SD), median [IQR] or %
Patients	
Age (years)	26.1 (11)
Sex (M/F), %	60.2/39.8%
Delay to diagnostic (months)	16.9 (15.2)
Pain (NS)	8 [8–9]*
Imaging	
Localization (%)	Femur: 43.2%
	Tibia: 21.6%
	Talus: 5.7%
	Humerus: 5.7%
	Fibula: 4.5%
	Others: 19.3%
Nidus size (mm)	5.8 (1.8)**
Calcification size (mm)	2.4 (1.8)**
Procedure	
Anesthesia (%):	
General	64/86 (74.4%)***
Locoregional	20/86 (23.3%)***
Conscious sedation	2/86 (2.3%)***
Needle size 7/10 mm (%)	62/38%
Number of ablations	1 [1–2]
Needle targeting	
Transfixing (%)	95.2%†
Centered (%)	71.1%†

*Evaluated on 75 patients, **evaluated on 87 patients, ***evaluated on 86 patients

†Evaluated on 83 patients

Results

Study population

During the study period, 126 patients were treated by CT-guided RFA for OO in our academic center. Among them, five patients were excluded because of alternative diagnosis found on the biopsy (Fig. 2 flow chart and Fig. 3), and 33 patients were excluded because they did not answer the follow-up call. Eighty-eight patients were included in the

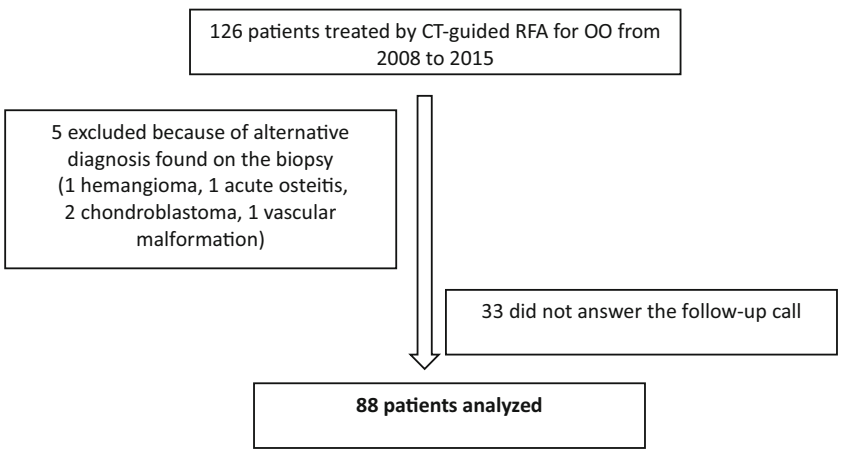


Fig. 2 Flow chart

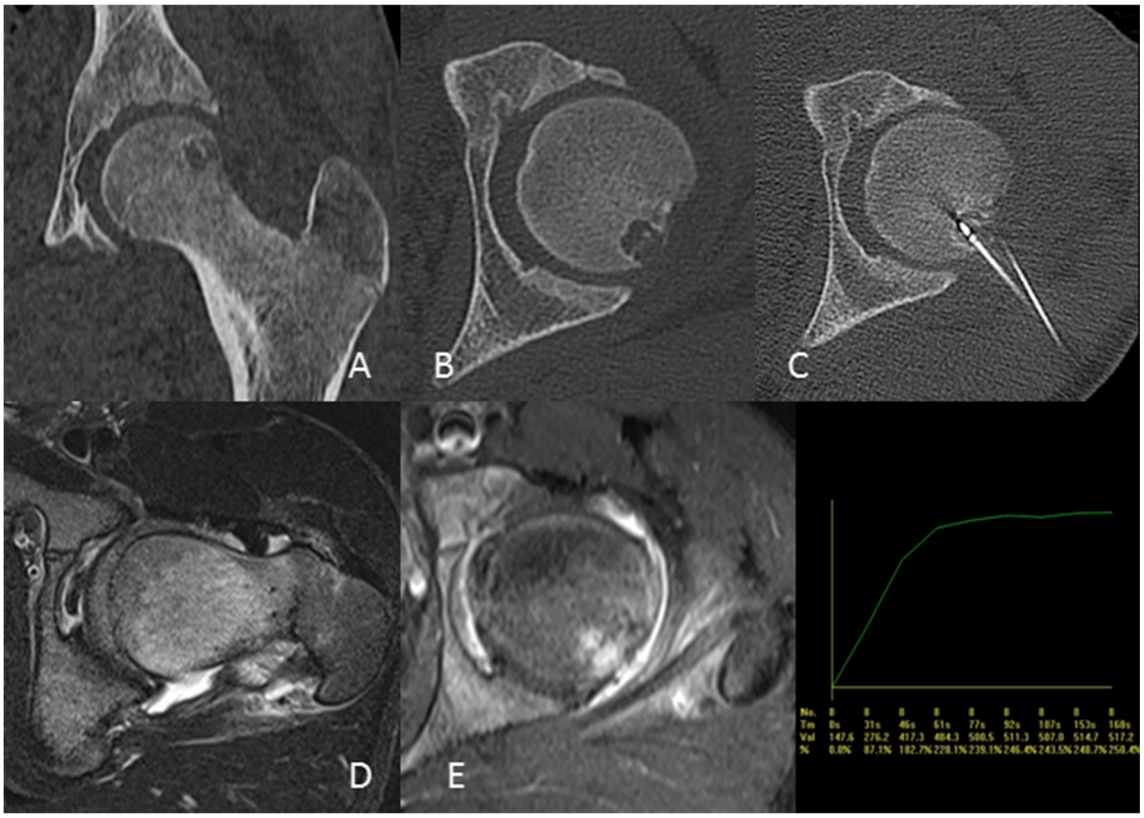
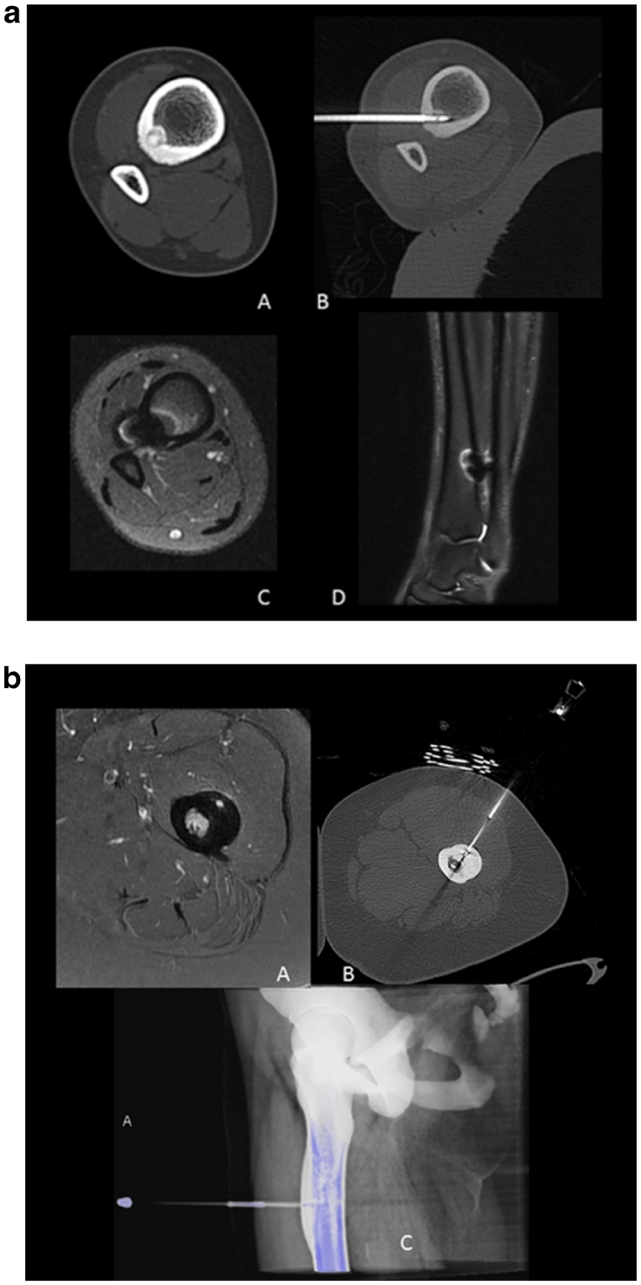


Fig. 3 Alternate diagnosis on biopsy: 15-year-old male with inflammatory hip pain. A 10-mm osteolytic lesion of the left femoral epiphysis with peripheral sclerosis on CT (A and B), medullar edema and synovitis on the STIR sequence (D), and contrast uptake (E). The differential diagnosis including osteoid osteoma or chondroblastoma. The RFA procedure was performed (C) with a biopsy confirming the diagnosis of chondroblastoma

analysis. Patient characteristics are summarized in Table 1. Patients were mostly (60.2%) males, with a mean age of 26.1 years and a mean delay to diagnosis of 16.9 months. Median pain before the procedure was 8/10. Night pain was present in 84/88 patients (95.5%), and NSAIDS were effective in 56/88 patients (63.6%), ineffective in 14 patients (15.9%), and had not been used by 18 patients (20.5%). The most frequent OO locations were the tibia and femur, mean nidus size was 5.8 mm, and 15/88 (17%) OO were >7 mm; 74.4% of the procedures were performed under general anesthesia, 23.3% under locoregional anesthesia, and 2.3% under conscious sedation, with no significant difference in terms of early postoperative pain (23.4%, 10%, and 0%, $p = 0.49$). The needle was transfixing in 95.2% of cases and centered in 71.1%. In four cases, the needle was not transfixing because of technical difficulties in needle placement, with no difference in nidus size in these patients (6 versus 5.7 mm, $p = 0.44$). Among the 57 patients whose lesions were successfully biopsied, only 13 had definite histologic confirmation of the diagnosis (22.8%).

Outcome results

Mean follow-up time was 34.6 months (SD = 24.7, range 3–90). Primary success was obtained in 79/88 cases (89.8%), and primary or secondary success was obtained in 83/88 (94.3%) patients. Mean age in patients who failed initial treatment was 24.7 years versus 26.3 years in patients with primary success ($p = 0.35$). At the end of the follow-up, failure occurred in 5/88 (5.7%) patients. There was no difference in median pre-procedure pain scores between success and failure cases (8 versus 8.5, $p = 0.97$). The five failure cases are presented in Fig. 4. In failure cases, the electrode was located inside the lesion in 4/5 patients (and was tangential in the other case) and was centered in the lesion in 3/5 patients. Only one failure case had part of the osteoma located >5 mm from the electrode (Fig. 4e). Minor complications (5.7%) occurred in five patients: two mild reversible peripheral nerve injuries (mild hypoesthesia involving branches of the femoral cutaneous nerve), one postoperative positioning brachial plexus neuropathy, one broken electrode tip fragment, and one muscular



◀ **Fig. 4** Five cases with RFA failure. **a** Case 1: 18-year-old female with a 6-mm nidus of the right tibial diaphysis (A). Delay to diagnosis was 12 months, and pre-procedure pain was 9/10. The procedure (B) was performed under general anesthesia. Immediately after the procedure, pain dropped to 4/10 and persisted at the same level at the 35-month follow-up, without daily life activity impairment, compatible with an incomplete initial treatment. No residual nidus was however seen on follow-up imaging studies. MRI (C and D). **b** Case 2: 24-year-old female with a 4-mm nidus of the left femoral diaphysis (A). Delay to diagnosis was 24 months, and pre-procedure pain was 10/10. The procedure (B and C) was performed under general anesthesia. Immediately after the procedure, pain remained at 9/10 the first 6 months; it then dropped to 5/10 and persisted at the same level at the 43-month follow-up, causing limitations in daily life activities, compatible with an incomplete initial treatment. The patient however complains of potentially confusing chronic back pain. **c** Case 3: 15-year-old female with a 5-mm nidus of the right fibular diaphysis (A). Delay to diagnosis was 30 months. The procedure (B) was performed under general anesthesia. Immediately after the procedure, pain decreased with some occasional pain and then reappeared 3 months after the procedure. DCE MRI showed a post-therapeutic pattern, with moderate contrast uptake of the treated area suggestive of scar tissue (C). **d** Case 4: 16-year-old male with a 5-mm nidus of the right femoral diaphysis. Delay to diagnosis was 10 months, and pre-procedure pain was 8/10. Procedure (A) was performed under general anesthesia. After the procedure, pain decreased to 0 and then reappeared 1 year later, with imaging (CT and MRI) compatible with OO recurrence (B and C). After the second RFA (D), pain decreased to 0 and then reappeared again 6 months later. The patient was then successfully treated by surgery, with no residual pain at the 67-month follow-up. **e** Case 5: 13-year-old female with a 7-mm nidus of the right articular process of L5. Delay to diagnosis was 6 months, and pre-procedure pain was 5/10. Procedure (A) was performed under conscious sedation. The needle was not located inside the lesion (maximal distance from lesion to electrode: 6 mm), and biopsy was performed within the peripheral sclerosis, showing a non-specific chronic osteitis. After the procedure, the pain decreased to 0 and then reappeared 5 months later with scintigraphic features of OO recurrence (B). A second RFA (C) was performed, using epidural temperature monitoring and aeric insulation. Pain decreased to 0, but reappeared 3 years later with episodes of sciatica. Follow-up MRI showed a post-therapeutic pattern with a post-therapeutic progressive capsular uptake of the posterior facet joint and no evidence of OO recurrence

hematoma. These five patients were however free of OO-related pain and able to perform activities normally and were therefore considered as technical successes of the RFA procedure.

Discussion

Our study followed, whenever possible, recent guidelines for the reporting of series of RFA-treated OO [4]. Our results confirm that RFA is a treatment of choice for OO. Using the same ablation device (straight-tip electrode) for all patients, our success rate is excellent on pain and ability to perform daily activities, in line with those reported in previous studies [5–8] and in a recent review on 1772 patients [4]. The long-term follow-up in our study confirms the persistence of the beneficial effects of the treatment as treatment failures can be due to incomplete treatments or recurrences that may happen several months after the initial procedure. In the study population, the complication rate was low, and only minor complications occurred. Treatment failure occurred in five cases: OOs were located in the femoral diaphysis (n = 2), tibial diaphysis (n = 1), fibular diaphysis (n = 1), and L5 articular

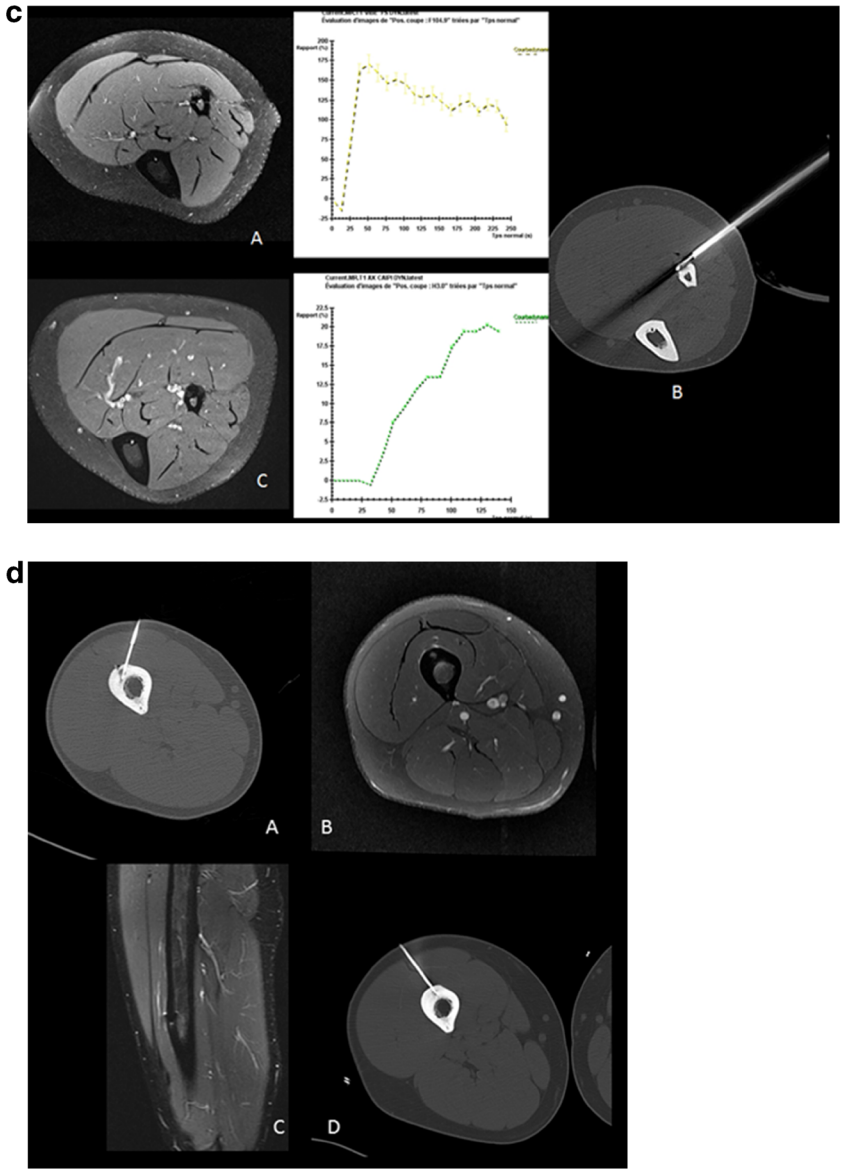


Fig. 4 continued.

process (n = 1). Pain persisted, although reduced, after ablation in two cases and, in the three other cases, decreased and reappeared several months (3, 5, and 12) after procedure with imaging (MRI, bone scan, and CT) features suggestive of recurrence. Unsuccessful secondary ablation was performed in two cases, one of which was then treated surgically, with no residual pain afterwards.

The usefulness of per-procedural biopsies is debated in the literature because of its variable confirmation rate, ranging from 27 to 76% [9–12]. When successfully performed in our study (n = 57/88), biopsy was often not contributory. Indeed, histologic confirmation of OO occurred in only 13/57 (22.8%) cases. This can be due to several factors: (1) the small size of the tumors leading to inadequate sampling, (2) the small caliber of our biopsy needle (18-gauge core sample size) [12], and (3) difficulties in drilling leading to a fragmented and compacted biopsy sample or in some cases insufficient biopsy material.

Our study has some limitations. First, the low treatment failure rate did not allow us to perform a multivariate statistical analysis of the factors associated with treatment failure, such as tumor size [6, 7], number of ablations [6, 13], or needle positioning [14]. However, failure cases are detailed in this study, and essential parameters are reported to allow for future meta-analysis [4]. Moreover, the retrospective nature of the outcome evaluation, occurring a long time after the procedure, did not provide accurate information on early postoperative pain evolution in the first week for all patients. Furthermore, due to memory gaps in many patients, the precise intermediate (1 week, 1 month, 6 months) time points used to conduct the

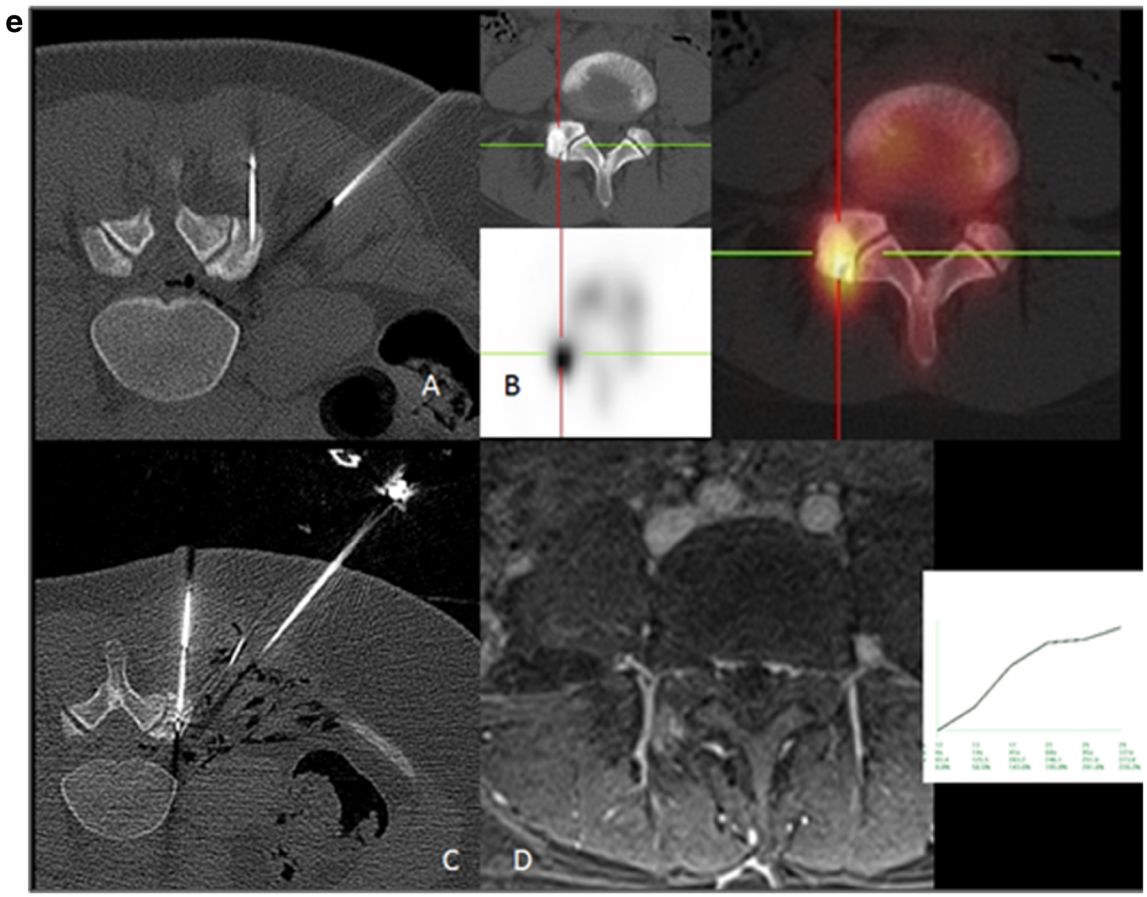


Fig. 4 continued.

follow-up interview were not always accurately assessable. Lastly, clinical and imaging follow-up is not performed routinely after RFA in our institution; we therefore lacked clinical data for many patients who were lost to long-term follow-up. The excluded patient subset seems unlikely to skew the study results, as it consists solely of patients of who could not be reached at all for the follow-up interview (no patients refused to respond, once reached).

Conclusion

Osteoid osteoma can be effectively and safely treated by CT-guided RFA. Beneficial effects of the percutaneous treatment persist at long-term follow-up.

Compliance with ethical standards

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

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