ABSTRACT
Objective: To observe the necessity and usefulness of follow-up Magnetic Resonance Imaging (MRI) and Computed Tomography Imaging (CTI) after RFA of osteoid osteoma.
Study Design: A descriptive study.
Place and Duration of Study: Department of Radiology, Sisli Etfal Training and Research Hospital, Istanbul, Turkey, between May 2015 and January 2020.
Methodology: Patients, who underwent CT-guided RFA for osteoid osteoma treatment, were followed-up both clinically and radiologically. MRI was recommended between the third and sixth months and CTI at 12th month or later for follow-up. All the pre and post-treatment radiological images were evaluated retrospectively. Radiological recovery was noted in three categories as complete/almost-complete, partial, and minimal-no recovery according to the healing of pre-treatment radiological findings.
Results: One-hundred and thirty-one patients with at least one follow-up CT or MRI were included. All had technically and clinically successful RFA treatments. Of 131 patients, 64.1% had CTI and 82.4% had MRI follow-up. In follow-up images, complete/almost-complete-recovery was observed in 70.2%, partial recovery in 26.7%, and minimal recovery in 3.1% of the cases. Re-ablation therapies were applied in 2 cases in this study due to pain recurrence after three months of successful treatments.
Conclusion: Radiological follow-up is beneficial for the evaluation of outcome after RFA of osteoid-osteoma. At least one follow-up MRI may be helpful for the assessment of healing or recurrence. Follow-up CTI may not be needed unless planning a re-ablation.
Key Words: Osteoma osteoid, Radiofrequency ablation, Tomography, Magnetic resonance imaging.

INTRODUCTION
Osteoid osteoma (OO) is a benign bone tumor presented with pain symptom.1-8 Radiofrequency-Ablation (RFA) has been preferred as the first choice of treatment. After RFA, noticeable pain relief occurs mainly within 24 hours.1-8 Previous studies have established the details about the radiological findings of OO, RFA procedure, and clinical follow-up findings after treatment.1-10 However, radiological success and expected radiological findings have been uncertain and there are few reports.11-14 Although clinical recovery is satisfactory, an objective indicator as radiological demonstration of treatment response is needed. Being familiar with regular postablative radiological changes and being aware of the expected and unexpected radiological findings after RFA may provide a better evaluation of the patients with pain recurrence. The present follow-up radiological findings of both clinically successful and unsuccessful treatments may be helpful to understand what is expected and what is not.
This study aimed to observe the usefulness and necessity of radiological follow-up after RFA. To the authors knowledge, this is one of the very few reports demonstrating radiological recovery of OO with demonstrative Magnetic Resonance Imaging (MRI) and Computed Tomography Imaging (CTI) findings.

METHODOLOGY
The study was approved by the Institution’s Ethical Committee (Number: 1879; Date: 23.01.2018). Informed patients’ consent were obtained from all the patients for RFAs and follow-up radiological examinations. Patients, who had CT-guided RFA between May 2015 and Jan 2020 at the Department of Radiology, Sisli Etfal Training and Research Hospital, Turkey, were included. Two inter-
ventional radiologists performed all the interventions with 13 and 6 years of interventional radiology experience. All the patients already had diagnostic pretreatment MRIs and CTIs when they were admitted to the interventional radiology clinic. After the interventions, for radiological follow-up, MRI (without contrast medium administration) was recommended between the third and sixth months and CTI after the 12th month. Follow-up MRI was recommended for all the patients (if possible and could be done without sedation in pediatrics). Follow-up CTI was not routinely recommended for the patients younger than a 10-year-old to protect them from irradiation except for suspicious findings on follow-up radiographic images or clinical requirements. All the CT examinations were performed under the supervision of the radiologist who performed the interventions to obtain a targeted low-dose CT examination. Shields were used to protect the gonads during CT examinations.

Patients with at least one follow-up MRI and/or CTI were included in the study. Patients who were lost for follow-up or did not accept the invitation for follow-up radiological imaging were excluded. All the follow-up MRIs and CTIs were evaluated retrospectively. Radiological findings such as healing of the nidus, reactive sclerosis, periosteal reaction, regression of reactive synovitis, edema (in bone-marrow and adjacent soft tissue), and recovery of muscle atrophy were evaluated by comparing the pre and post-treatment images. Healing of these findings was considered as recovery while worsening was considered as relapse. The radiological response was assessed according to the last follow-up radiological findings of either MRI or CTI. Response to the treatment was noted in three categories in accordance to recovery rate of radiological findings as complete/almost-complete, partial, and minimal-no recovery. If regression of the pretreatment radiological findings (such as healing of edema in bone-marrow and adjacent soft-tissue), reduction of joint synovitis, recovery of reactive sclerosis, regression of periosteal thickening, healing of muscle atrophy, mineralization of nidus) was clearly prominent compared to the posttreatment findings, it was defined as complete/almost-complete radiological recovery. If edema/synovitis prominently regressed while periosteal thickening/sclerosis or muscle atrophy slightly regressed, it was defined as partial radiological recovery. If there was no prominent change in any of the pretreatment findings, it was defined as minimal-no recovery accordingly.

For statistical analysis, Statistical Package for the Social Sciences (SPSS) for Windows (Version 15.0, Chicago, SPSS Inc.) program was used. Descriptive statistics were given as numbers and percentages for categorical variables and mean, standard deviation, minimum, maximum, and median for numerical variables.

RESULTS

A total of 131 patients [90 (68.70%) males and 41 (31.30%) females; mean age 16.0 ± 7.58 years] with at least one follow-up CTI or MRI were included in this study. Considering the localization of the OOs, 84 (64.12%) of them were localized in the femur head, neck, and diaphysis. The mean follow-up period was 38 (8-59) months and 123 (94%) of the patients had more than 1-year of follow-up.

All the patients had pretreatment CTIs as a part of the routine diagnostic workup. Also, 124 (95%) of the patients had pre-treatment MRIs. After RFAs, 84 (64.1%) had CTI and 108 (82.4%) had MRI follow-up. Forty-two (32.1%) of the patients had more than one follow-up MRI while none had more than one follow-up CTI.

Evaluating the technical and clinical success, all the patients had successful RFA treatments that all were pain-free in 24 hours. The Re-abloation therapies were applied in 2 cases due to known OO pain recurrence on the 12th and 29th months. Nine minor complications were seen related to the RFAs and all were treated successfully. No major complications occurred.

Evaluating the radiological success with follow-up CTIs and MRIs, complete/ almost complete-recovery (reduced size of the niduses, its surrounding sclerosis, amount of edema in bone-marrow or adjacent soft-tissue, and posture-deformity) was observed in 92 (70.2%), partial-recovery in 35 (26.7%), and minimal-recovery in 4 (3.1%) of all cases.

DISCUSSION

In OO patients, the most crucial determinant factor in evaluating the response to treatment is pain-relief. However, it is a matter of curiosity whether the radiological response accompanied the clinical response. Current studies in the literature have shown that, although radiological response supports clinical response, it does not always reflect the success of the procedure.

In this study, considering 83% of the patients presented with a complete/almost complete radiological recovery, the radiological success supports the clinical success substantially (Figure 1). On the other hand, although 17% of the patients had a partial or minimal recovery, none had pain relapse. This result supports the fact that radiological recovery may be partial, although the clinical recovery is total.

While the clinical response may be present within a short period, such as 24 hours, seeing the radiological response may take longer. Since there is no specific algorithm or recommendation for optimal follow-up times, different follow-up protocols were established in the upcoming literature. As there was insufficient experience in...
Radiological follow-up is especially beneficial to diagnose a recurrence. For example, in the first follow-up MRI of a patient after RFA, reduction of bone marrow and soft tissue edema supports healing of an OO and benefit of a treatment. If relapse of the pain develops in the same patient, re-occurrence of the edema in the second follow-up MRI strongly supports the relapse of the OO. Then a second RFA can be planned undoubtedly. In this study, re-ablation therapy was applied in 2 cases due to the pain recurrence (11 and 13-year boys who had OOs in femur-diaphysis). Recurrence of edema in bone marrow and adjacent soft tissue were the signs of relapse in both of the patients. Follow-up MRIs were supportive and beneficial for planning re-ablation therapies (Figure 2).

Follow-up imaging is not only valuable in terms of monitoring the OO nidus and reactive sclerosis but also in monitoring the secondary radiological findings. In two patients (a 10-year-girl and a 12-year-boy with OOs in the femur-neck), who had intra-articular OO, edema, and periarticular synovial-fluid persisted for 18 and 28 months after RFA, respectively. An increase was observed in periarticular synovial-fluid amount which could be assumed as pseudo-progression (Figure 3). Since children had no pain relapse, re-ablation was not planned. The boy was referred to physical-rehabilitation-therapy due to postural-distortion and secondary muscle atrophy occurred as a long-term outcome of OO. The girl recovered faster and did not need physical therapy. Given these two patients, regression of extra-synovial fluid may be prolonged in especially intra-articular OOs. In two other patients, post treatment muscle atrophy occurred due to tendon injury in needle-track and they have recovered after receiving physical therapy. It should be kept in mind that post treatment MRI is also necessary to evaluate procedure-related secondary radiological findings.

Follow-up CTI and MRI findings have demonstrated that RFA is effective and safe in OO treatment. Although the radiological response is a strong indicator of success, a late or weak response does not indicate that the treatment has failed. Radiological recovery of OO after RFA may occur much later than clinical recovery. Follow-up MRI is beneficial, primarily if performed later than the 3rd month, and mineralisation of the nidus is better seen after the 12th month in CTI. After RFA, at least one follow-up MRI may suggest evaluating the treatment outcome and monitoring the healing or worsening of the radiological findings. A routine follow-up CTI may not be needed unless planning a re-ablation due to pain relapse.

**CONCLUSION**

Follow-up CTI and MRI findings have demonstrated that RFA is effective and safe in OO treatment. Although the radiological response is a strong indicator of success, a late or weak response does not indicate that the treatment has failed. Radiological recovery of OO after RFA may occur much later than clinical recovery. Follow-up MRI is beneficial, primarily if performed later than the 3rd month, and mineralisation of the nidus is better seen after the 12th month in CTI. After RFA, at least one follow-up MRI may suggest evaluating the treatment outcome and monitoring the healing or worsening of the radiological findings. A routine follow-up CTI may not be needed unless planning a re-ablation due to pain relapse.

**ETHICAL APPROVAL:**

The study was approved by the Ethical Committee of Istanbul Sisli Hamidiye Etfal Training and Research Hospital (No. 1879; Date: 23.01.2018) and was conducted in accordance with the 1964 Helsinki declaration.

**PATIENTS’ CONSENT:**

Informed patients’ consents were obtained from all the patients for RFAs and follow-up radiological examinations.

**COMPETING INTEREST:**

The authors declared no competing interest.

**AUTHORS’ CONTRIBUTION:**

CS, AHB: Planned and performed the interventions and supervised radiological follow-up examinations.

MAT: Performed orthopaedic physical examinations.
REFERENCES


