Osteoid osteomas, first described by Jaffe in 1953, are small (10–20 mm) bone-forming tumors. They represent 10% of benign primary bone tumors and usually occur between the 2nd and 3rd decades of life with a male predominance (male/female 3:1); 10% of these tumors affect the spine. Localized pain, secondary to increased levels of prostaglandin E2 at the osteoma’s nidus, is the main symptom at presentation for all locations. An osteoid osteoma usually responds to medical treatment consisting of nonsteroidal antiinflammatory drugs (NSAIDs) and salicylic acid. Spinal osteoid osteomas may be complicated by painful scoliosis and rarely by neurological deficit.

Diagnosis of osteoid osteomas is based mainly on CT...
scanning findings, which characteristically show a hypodense region surrounded by a sclerosis of varying intensity.\textsuperscript{14} On nonenhanced MRI, the nidus is optimally visualized on T2-weighted sequences, when it appears as a hypointense lesion surrounded by marrow edema. Peri nidal enhancement is observed after gadolinium administration.\textsuperscript{6}

Conservative treatment using NSAIDs and salicylic acid is considered by many to be the treatment of choice for spinal osteoid osteomas.\textsuperscript{2,3} Interventional treatment must be considered for cases refractory to analgesic agents or in patients in whom these medications are either contraindicated or not tolerated.\textsuperscript{5} Interven tional management includes complete resection of the lesion and radiofrequency ablation (RFA).\textsuperscript{16,17} However, the use of RFA technique in the treatment of spinal osteoid osteomas is still controversial due to the proximity of the lesion to nervous structures and subsequent potential thermal injury to the spinal cord and exiting nerve roots.\textsuperscript{5} Therefore, we conducted an experimental study in rats in our laboratory to test the safety of the procedure when performed in the spine.\textsuperscript{9} The study demonstrated that a motor response threshold to electrical stimulation higher than 2.5 V is considered to be safe, reflecting a distance greater than 5 mm between the tip of the electrode and the adjacent nervous structure. Indeed, in this study, the presence of a cortical bone between the tip of the electrode and the nervous structure proved to be safe to these structures.

Based on these experimental results, the main objective of the current study is to evaluate the clinical safety and efficacy of RFA in the management of spinal osteoid osteomas.

**Methods**

**Patient Population**

Eight consecutive patients diagnosed with spinal osteoid osteoma were included in this prospective clinical study from the department of Neurosurgery at Hôtel-Dieu de France Hospital, Beirut, Lebanon, between March 2009 and July 2016. Inclusion criteria were presence of spinal osteoid osteoma without any other neurological or spinal disorder confirmed by spinal CT scanning read by the same radiologist. Exclusion criteria were presence of neurological or spinal disorder revealed by abnormal clinical examination or abnormal imaging results, abuse of analgesic agents, current psychiatric disorder, pregnancy in women, and patients who could not be followed up reasonably or could not clearly express and sign their informed consent.

All patients who chose to participate gave written informed consent. Protocols were approved by the local ethics committee at both Saint Joseph University and Hôtel-Dieu de France Hospital. The study was conducted according to the declaration of Helsinki\textsuperscript{13} and of the World Medical Association (www.wma.net).

**Clinical and Radiological Assessment**

There were 5 female and 3 male patients with a mean age of 28 years (range 12–44 years). Patients underwent general and neurological examinations performed by the same 2 senior neurosurgeons. All patients had normal neurological examination findings before the procedure. Table 1 provides detailed clinical and demographic information of the patient sample. All patients presented with pain typically occurring at night, with pain relieved by the administration of NSAIDs. The average duration of symptoms before the presentation was 12 months (range 4–24 months), and response to salicylate was noted in 50% of the cases. The median preoperative visual analog scale (VAS) score on a ruler with a slide indicator (on the front there are no digits for patient, only a line from “No Pain” to “Worst Imaginable Pain”) read on the reverse by the examiner (0 indicates being pain free and 10 indicates the worst imaginable pain), was 7.55 (range 6–8.8).

The radiological diagnosis of osteoid osteoma was based on CT scanning findings (Fig. 1). The characteristic findings of a hypodense region surrounded by a sclerosis of varying intensity were noted in 7 of the 8 patients. The lesions had a mean diameter of 0.99 cm (range 0.4–2 cm).

The osteoid osteomas were located mainly in the posterior elements and were found, in descending order of frequency, in the lumbar (4 patients), thoracic (3 patients), and cervical (1 patient) spine.

**Operative Technique**

The operation was performed in the CT room under general anesthesia. The patient was positioned on the CT table in such a way as to allow access to the preferred entry site as determined on the initial diagnostic CT scan, based on the localization of the osteoid osteoma and the adjacent nervous structures. A scout view was then obtained through the lesion, and the nidus was localized us-
ing 1-mm cuts followed by percutaneous introduction of a needle trocar followed by a bone biopsy cannula to the center of the nidus. The needle trocar was then removed, and the electrode (outer diameter 0.5 mm, 2-mm exposed tip, built-in thermistor) was introduced through the cannula into the center of the nidus (Fig. 1).

A motor threshold test was then performed using a generator (F. L. Fischer, INOMED Medizintechnik GmbH). The electrode impedance was measured (< 1000 Ω). Electrical stimulation was performed at 2 Hz, with intensity increased by 0.1-V steps. When no motor response is observed until 2.5 V, the tip of the electrode is considered to be at a safe distance of at least 5 mm of the adjacent nervous elements, based on the experimental study published by our team. After the motor response threshold test was performed, the electrode was connected to a radiofrequency generator (Neuro N50, IEC 601–1, FDA, UL-listed, Med.GB), which delivered a radiofrequency of 500 kHz with a controlled temperature of 82°C. This temperature was maintained for 4 minutes.

A final control CT scan was obtained before withdrawal of the electrode. All patients were discharged 24 hours after the procedure with oral analgesics (NSAIDs and paracetamol for 1 week) and immediately resumed their daily activities.

Patient Follow-Up and Assessment

Pain, as determined by the VAS score, and neurological deficits were reassessed immediately before discharge, with further follow-up performed within 1 day and at 1, 6, and 12 months after the procedure. Thereafter, the VAS, neurological examination, patient satisfaction, and a radiological control (CT scan, obtained in 50% of patients) were documented at a median final follow-up of 48 months (range 12–84 months). The use of oral analgesics was also noted.

Statistical Analysis

Preoperative and postoperative VAS scores were compared during the 3 days before the procedure, on Day 1, and at the final follow-up using the Wilcoxon test (Stata...
version 12, StataCorp). A p value < 0.05 was considered to be statistically significant.

Results

Side Effects and Postoperative Neurological Clinical Evaluation

No patient developed a neurological deficit (motor or sensory) after the radiofrequency procedure. All patients left the hospital the day after the procedure and resumed their normal activities on Day 7. The neurological examination findings remained normal at the final follow-up.

Pain Intensity and Patient Satisfaction

Pain intensity, measured using the VAS, was significantly reduced at Day 1, compared with the mean pain intensity during the 3 days before the procedure (p = 0.005). At final follow-up (median 48 months, range 12–84 months), no patient had any pain (VAS Score 0 for all) (Fig. 2) and all had a subjective satisfaction rate of 100% on a scale from 0% to 100%. Analgesics (NSAIDs and paracetamol) upon request were used for 12 ± 4.34 days (± SD) following the procedure. At the most recent follow-up, all patients were medication free for their osteoid osteoma.

One patient (Case 5) had recurrent symptoms of localized pain (VAS Score 8.1) 6 months after the initial radiofrequency procedure without associated neurological deficit. A SPECT bone scan demonstrated a focus of increased activity at the level of the right L-4 isthmus (previous site of the osteoid osteoma). A second procedure was then performed using the same operative technique, and the patient was symptom free (VAS Score 0) at the final follow-up 40 months after the second procedure.

Radiological Control

All patients underwent postoperative control CT scanning (Fig. 3). The median duration between the radiofrequency procedure and the control CT was 48 months (range 12–84 months). Among these patients, 4 had regression of the typical lesion with persistence of residual sclerosis, and 4 had normal results on CT scanning with complete resolution of the radiological lesion.

Discussion

Based on the results of a previous experimental study in which we determined the safety parameters for the use of radiofrequency in the spine, we found in the current prospective clinical study that radiofrequency is a safe and valid method for the treatment of spinal osteoid osteomas, with excellent long-term results. This condition may thus be managed in a mini-invasive way, avoiding more aggressive neurosurgical treatment.

Characteristics of the Population

In our small series of patients presenting with spinal osteoid osteomas, we noted a female predominance with a sex ratio of 5:3, in contrast with the reported 1:3 ratio in the literature. This difference is most probably due to the small number of patients in our study as well as recruitment bias. The mean age at presentation was 28 years and was in accordance with the reported typical age of presentation before the age of 30 years. Similarly, all patients suffered from predominant nocturnal pain, which partially responded to salicylate in half of the patients, in line with the literature. In addition, most of the osteoid osteomas (7 of 8 patients) were located in the posterior vertebral elements, in accordance with other series.

Safety of the Procedure

As stated above, the safety parameters used in this clinical study are issued from a previous experimental study in rats. Our results confirm the reported safety of the RFA technique in the treatment of spinal osteoid osteomas since all of our patients had normal results on neurological examination following the procedure without any motor or sensory deficit. No other general or local complications were noted. In this context, respecting a minimum distance of 5 mm between the tip of the electrode and the adjacent nervous structure based on CT scanning and verifying a motor response threshold more than 2.5 V ensure the absence of nervous thermal lesions induced by the radiofrequency. In addition, the presence of a cortical bone between the tip of the electrode and nervous structure is considered a safe CT scanning parameter, as demonstrated previously in rats.

Alternative Therapies for Spinal Osteoid Osteomas

Despite the documented efficacy of NSAIDs in pain relief of osteoid osteomas, intervention treatment is indicated when these agents fail, or to avoid long-term use of antiinflammatory medication. Surgical excision of the lesion has long been considered the treatment of choice in these cases refractory to medical management. However, resection is associated with many potential complications and challenges, such as identifying the lesion during surgery, performing complete removal, inducing instability secondary to a wide resection with subsequent need for fusion, and the possibility of cauda equina or cord injury. Pettine and Klassen reported their experience at the
Mayo Clinic of 31 patients who underwent en bloc excision of spinal osteoid osteoma. In 11 of these 31 patients, excision was combined with fusion. In addition, 11 patients required more than 1 procedure, 5 because the operation was performed at the wrong location, 1 because of inadequate resection, 4 after initial surgery elsewhere, and 1 required a (staged) front and back fusion. Contrasting with these results, in our series all patients were discharged 24 hours after the procedure and immediately resumed their daily activities. Regarding complications, 3 patients sustained a nerve lesion secondary to the surgical procedure in the Pettine and Klassen series, while in our study all patients had normal results documented at the postoperative neurological examination.

A second procedure was needed for recurrent pain in 1 of our patients 6 months after the initial intervention. After this second RFA procedure, the patient was pain free at the final follow-up 40 months later.

Long-Term Follow-Up and Clinical Outcome

Radiological follow-up using CT scanning showed regression of the nidus with persistence of residual sclerosis in 4 patients and complete disappearance of the nidus in 4 patients. The patients with normal findings on CT scanning underwent control CT at 12, 48, 76, and 84 months (1 patient at each time period) after the procedure, while all patients showing regression of the nidus with sclerosis had their control within less than 52 months. Our study suggests progressive regression of the nidus on serial radiological imaging. The necrosis induced by the RFA will decrease levels of prostaglandins secreted by the osteoid osteoma nidus, which correlate with the observed clinical improvement.

Limitations of the Study

Major limitations of this study are the limited number of enrolled patients from a single medical institution and the lack of histological proof of the lesion. However, although ours is not the largest patient population studied to determine the efficiency of RFA in the treatment of spinal osteoid osteoma, our study has the advantage that the safety of the procedure for spinal lesions was established by prior experimental study in rats.

Conclusions

CT-guided RFA appears to be a safe and effective method for treating spinal osteoid osteoma and can be safely performed for lesions close to the dura or exiting nerve roots based on motor response threshold testing performed intraoperatively. RFA is a relatively noninvasive treatment modality for osteoid osteoma that has demonstrated long-term radiographic control and pain relief without the additional morbidity of open surgery. It can be easily repeated in nonresponsive cases. Future large, multicentric, and well-controlled studies are needed to definitely validate the use of this mini-invasive technique in the management of spinal osteoid osteomas and establish its long-term efficacy.

References


**FIG. 3.** Axial CT scans centered on the osteoid osteoma after the radiofrequency procedure of the 8 patients included in this study. Postoperative control CT scans were obtained between 12 and 84 months (median 48 months) after the procedure.

Disclosures
The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions
Conception and design: Maarrawi. Acquisition of data: Maarrawi, J Faddoul, Y Faddoul, Kobaiter-Maarrawi. Analysis and interpretation of data: Maarrawi, Y Faddoul, Kobaiter-Maarrawi. Drafting the article: Maarrawi, J Faddoul, Y Faddoul, Kobaiter-Maarrawi, Moussa, Nohra. Critically revising the article: Maarrawi, J Faddoul, Kobaiter-Maarrawi, Moussa, Rizk, Okais, Samaha. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Maarrawi. Statistical analysis: Maarrawi. Study supervision: Maarrawi.

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