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Radiofrequency ablation of osteoid osteoma

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CONTENTS

Chapter 1

Introduction

Osteoid osteomas were first described by Jaffe in 1935 (1). They represent 10-15% of all benign bone tumours and mainly occur in the lower extremity (femur and tibia) of children and young adults. A spinal location is seen in 10% of osteoid osteomas. Osteoid osteomas are more common in males than females (ratio 2:1). Most affected individuals complain of pain typically worsening at night. Associated function loss may be present. The pain is often relieved by treatment with salicylates or other non-steroidal anti-inflammatory drugs. The mean duration of symptoms prior to diagnosis is 16 months (2-4).

Histologically osteoid osteomas are composed of a variably calcified small nidus composed of osteoblasts and osteoid. These are arranged in a meshwork pattern and are embedded in a fibrous stroma containing vascular and neural structures (2-4).

Radiographically, osteoid osteomas present as a radiolucent nidus with surrounding sclerosis. Conventional radiographic features are often subtle. The imaging features of osteoid osteoma are better demonstrated on thin-slice computed tomography (CT) (1-2 mm thickness). Radiographic criteria for the diagnosis of osteoid osteoma are the presence of a radiolucent nidus, usually not larger than 1.5 cm, with surrounding reactive sclerosis and often periosteal reaction. Osteoid osteomas demonstrate increased activity on bone scintigraphy. The role of magnetic resonance imaging (MRI) in the diagnostic work-up of osteoid osteoma is unclear. The associated bone marrow edema visible on MRI has been reported to lead to erroneous diagnoses such as a stress fracture or even a malignant bone tumour (2-4).

Until the early nineties surgery was the treatment of choice for osteoid osteomas. Apart from the localization problem of osteoid osteomas during surgery, post-operative complications are reported in 20 – 45% of patients (2). Complications include fractures especially in weight bearing bones such as the tibia (2). Other major post-surgical complications are infection and neurovascular injury (5;6). Bruneau et al described a rupture of the vertebral artery after surgery on a cervical osteoid osteoma (5).

The disadvantages of surgery have initiated the development of image-guided techniques such as percutaneous CT-guided radiofrequency ablation (2). Rosenthal et al (7) described in 1992 the first successful clinical application of CT-guided radiofrequency ablation in the treatment of osteoid osteoma. Radiofrequency ablation aims at the precise delivery of heat to the target tissue. High-frequency alternating current transmitted through the radiofrequency ablation electrode induces local ionic agitation and frictional heat resulting in coagulation necrosis (2).

CT-guided radiofrequency ablation is a less invasive treatment of osteoid osteoma. As a primary treatment radiofrequency ablation yields similar results as surgery (8), but with less complications. Complications related to radiofrequency ablation of spinal and non-spinal osteoid osteoma are infrequent and are related to inadvertent heating (skin burns) (7-15). Contrary to surgery (5;6;16-23), no major complications (infection or neurovascular injury) have been reported after radiofrequency ablation for spinal and non-spinal osteoid osteoma (7-15). Moreover, radiofrequency ablation can be easily repeated after initial treatment failure.

PURPOSE AND OUTLINE OF THE THESIS

The main purpose of this thesis was to evaluate the effectiveness and safety of CT-guided radiofrequency ablation for the treatment of spinal and non-spinal osteoid osteomas. Furthermore, the technical requirements needed for safe radiofrequency ablation and the clinical outcome after radiofrequency ablation of spinal and non-spinal osteoid osteomas are discussed. The possible causes of treatment failure and methods for the detection of treatment failure were also analysed with the purpose of optimizing patient selection and the radiofrequency procedures, and solving high risk parameters for failure of treatment.

Chapter two discusses the clinical outcome of a large series of 97 patients with spinal and non-spinal osteoid osteomas treated by radiofrequency ablation. **Chapter three** describes the theoretical and technical background of radiofrequency ablation. The concept of the treatment zone as well as related safety issues are also discussed. In **Chapter four** the possible mechanisms causing treatment failure are discussed. The potential role of CT and MRI imaging in the detection of recurrent or residual osteoid osteoma is addressed in **Chapter five**. Finally the treatment outcome of a group of 25 patients with spinal osteoid osteoma treated by radiofrequency ablation is presented in **Chapter 6**. A general discussion is provided in **Chapter 7**.

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Chapter 2

Thermocoagulation of osteoid osteoma: clinical results with thermocoagulation

ABSTRACT

Purpose: To determine the clinical results in an unselected group of consecutive patients with osteoid osteoma treated by thermocoagulation.

Materials and Methods: In 97 consecutive patients with clinical and/or radiological evidence for osteoid osteoma at any location, the clinical symptoms were assessed before and after thermocoagulation with computed tomographic guidance. A good response was defined as disappearance of symptoms that were manifested at presentation and attributed to osteoid osteoma. Clinical assessment was performed prior to discharge; within 2 weeks after the procedure; and at 3, 6, and 12 months follow-up. After 24 months, a postal questionnaire was used for assessment.

Results: The mean clinical follow-up after the only or last thermocoagulation was 41 months (range, 5-81 months). Response was good after one session of thermocoagulation in 74 (76 %) of 97 patients, and the 95% confidence interval (C.I.) was 68% to 85%. Patients with persistent symptoms did well after repeated thermocoagulation (good response in 10 of 12 patients), but results of repeated thermocoagulation were relatively poor in patients with recurrent symptoms (good response in 5 of 10). The overall success rate after one or two thermocoagulation procedures combined was 92 % (89 of 97 patients), and the 95% C.I. was 86% to 97%. Complications were observed in two patients.

Conclusion: Percutaneous thermocoagulation is a safe and effective method for treatment of osteoid osteoma at any location. Repeated thermocoagulation is successful in patients with persistent symptoms.

INTRODUCTION

Osteoid osteoma is a small painful benign tumor most frequently encountered in the first 3 decades of life (1). Treatment of choice used to be complete surgical excision. Surgical treatment, in which a substantial piece of bone is usually resected, may result in complications such as hematoma, infection and fracture. In addition, surgical treatment requires a long period of hospitalization, a period during which the patient cannot bear weight on the affected limb, and a delay in resumption of physical activity (2). Preoperative localization of the lesion may pose an additional problem. Preoperative localization of the lesion with computed tomographic (CT) guidance, for instance by placing a guide wire into the lesion preoperatively, has been used to reduce the chance of resecting normal bone while leaving the lesion behind (3).

These disadvantages have encouraged the introduction of less invasive therapeutic methods such as percutaneous excision, laser coagulation and thermocoagulation (2-11). Because of good short-term results, thermocoagulation was accepted as the prevailing technique at our institution several years ago. The purpose of our study was to determine the clinical results of thermocoagulation treatment in an unselected group of consecutive patients with osteoid osteoma.

MATERIAL AND METHODS

All consecutive patients who were identified in the Department of Orthopaedic Surgery at our institution and were clinically suspected of having an osteoid osteoma, whatever the location, were screened according to a standardized protocol. The protocol included the performance of radiography in two orthogonal directions, CT scanning with a reconstructed section thickness of 1-3 mm (Philips, Best, The Netherlands) and triple-phase bone scintigraphy. Four scanners, as mentioned later in this article, were used for CT, and a dual head system (GCA 901 A/w 2, GCA 7200; Toshiba Medical Systems, Tokyo, Japan) and a triple-head system for single photon emission CT (GCA 9300; Toshiba Medical Systems) were used for scintigraphy.

A clinical diagnosis of osteoid osteoma was determined when patients were complaining of nocturnal pain that was not related to physical activity and that was typically relieved or alleviated by salicylates or other nonsteroidal antiinflammatory drugs. The clinical suspicion of osteoid osteoma was confirmed with findings of additional imaging (i.e., radiography, scintigraphy and CT) according to criteria described in earlier studies. (1;12). Radiographic criteria were presence of a radiolucent nidus, varying in size from a few millimeters to 1.5 cm in diameter, with surrounding reactive sclerosis and, often, a periosteal reaction. The nidus may exhibit central calcification. The imaging features of osteoid osteoma are better demonstrated on CT than on radiographs (1).The nidus can be clearly differentiated from a reactive sclerosis and a periosteal reaction. Osteoid osteoma displays activity on both the immediate and delayed phase bone scintigrams. The lesion itself is characterized by a small focal area of increased activity surrounded by an area of less intense activity.

If clinical and imaging criteria were not all supportive of the diagnosis of osteoid osteoma (atypical manifestation in patients suspected of having osteoid osteoma), biopsy was performed to determine a histologic diagnosis. Only patients with a clinical follow-up of at least three months were included. Age and location of the lesion in the spine were not exclusion criteria. Informed consent (permission for the procedure as well as permission to use patient data for analysis) was obtained from all patients who met our criteria. Our institutional review board did not require approval for this type of study. Symptoms at presentation, interval between onset of these symptoms and determination of diagnosis, presence and site or absence of scoliosis, and use of medication were recorded.

From June 1994 to April 2000, 110 consecutive patients who had received a diagnosis of osteoid osteoma were treated with thermocoagulation. Four patients were excluded from this analysis because the follow-up data were incomplete. Nine recently treated patients were excluded because of short (less than three months), but symptom free follow-up. Thus, findings in 97 patients were analyzed. Biopsy was performed in 56 (58 %) of 97 patients, because not all typical clinical-radiologic criteria were present.

Ninety-seven patients (71 male and 26 female patients; mean age, 23 years; age range, 4-53 years) participated in this study. The male-female ratio was 2.7 male patients for each female patient. The lesions were located in the following areas: femur, 42 patients; tibia 14 patients; iliac bone or acetabulum, eight patients, talus, five patients; carpal bones of the hand, ulna and humerus, four patients each; lumbar spine and metacarpals of the hand, three patients each; fibula, navicular bone of the foot and cervical spine, two patients each; and cuneiform bone of the foot, dorsal spine, radius and phalanx of the hand, one patient each.

Nine (9 %) of these 97 patients had previous surgery before they were treated with thermocoagulation at our hospital. One patient was treated with thermocoagulation before elsewhere, but this procedure had failed because of technical reasons.

CT-guided thermocoagulation was performed by a radiologist and/or orthopedic surgeon, and the patient received regional or general anesthesia. The nidus was localized by using incremental CT (Tomoscan CXQ or LX; Philips Medical Systems, Best, the Netherlands) in 79 procedures and by using helical CT (Tomoscan SR 7000 or AV E1; Philips Medical Systems) in 42 procedures. After an incision of the skin that was 0.2 cm long was made, the center of the lesion was engaged initially by using a Steinmann pin (Synthes, Bettlach, Switzeland) in 40 procedures and, later, by using a biopsy needle system (Bonopty Penetration Set-REF 10-1072 and Bonopty Biopsy Set-REF 10-1073 and, if necessary, Bonopty Extended Drill-REF 10-1074; Radi Medical Systems, Uppsala, Sweden). If histologic analysis was needed a needle system (Jamshidi; Sherwood Medical, Belfast, Northern Ireland) was introduced over the K wire of the Steinmann system or the biopsy needle system drill was removed and exchanged for a 16-gauge biopsy needle.

The location of the needle was always assessed by CT. Finally, the biopsy needle was removed. Subsequently a 20-gauge 145-mm-long electrically isolated hollow needle (Sluijter-Metha Cannula; Radionics, Burlington, Mass) with an unprotected tip of 5 mm for use with radio-frequency probe and a radio-frequency probe (Radionics, Burlington, Mass) were introduced through the biopsy needle system.

The temperature at the tip of the thermocoagulation electrode was monitored during the procedure. The lesion was routinely heated to 90°C for 4 minutes by using a heating system (Radionics-RFG 3C RF- Lesion Generator System; Radionics).

After removal of the needle system, a CT scan was performed to assess if the nidus was reached and to check for possible complications.

The mean duration of the entire procedure was 90 minutes (range, 15-225 minutes). Discharge was scheduled for the same day, or the next morning. Patients were allowed to take acetaminophen (paracetamol) after treatment but only when they required this.

Before discharge, a clinical evaluation was performed to primarily assess pain. The same clinical assessment was performed within 2 weeks after the procedure and at 3, 6, 12, and 24 months follow-up. After 2 years, follow-up data were obtained by means of postal questionnaire, and if necessary, with a visit to the outpatient clinic. Not all patients finished the 2-year follow-up time. In the evaluation, the patient was asked if the pain was relieved, and if not, if it had ever been relieved and after what interval it returned. We defined a good response as disappearance of symptoms that manifested at presentation and were attributed to osteoid osteoma. When there was recurrent or persistent pain, the imaging protocol was again performed according to the initial protocol.

We defined a recurrence as the residual occurrence or recurrence of symptoms (pain and/or impaired function) that resembled the symptoms manifested at presentation and reappeared or persisted for more than 2 weeks after thermocoagulation was performed. The percentage of good respondents (patients who had a good response after one thermocoagulation session) and the 95% confidence intervals (C.I.s) were determined.

RESULTS

Symptoms prior to thermocoagulation

All patients experienced pain that was not related to physical activity. Pain was nocturnal in 41 (42%) of 97 patients. Seventy-seven (79%) of 97 patients were using medication, and 18 (19 %) were not. Information regarding medication use was not available in the remaining two (2%) patients. Some patients used more than one type of medication, and the response to medications (acetaminophen, 33 patients; aspirin, 26 patients; other nonsteroidal antiinflammatory drugs, 30 patients; other pain medications, such as codeine, one patient) was evaluated in 71 (73 %) of 97 patients. Thirty-three (46 %) of 71 patients had no or mild relief of pain, while 38 (54%) of 71 patients had good to complete pain relief.

Four (4%) of 97 patients had scoliosis; in one, scoliosis was in the cervical area of the spine, and in three, it was in the lumbar area.

Fifty-seven (59%) of 97 patients, including the four patients with scoliosis, had impaired function, which included limited motion and pain during movement of the affected limb or affected area of the spine, limping or stiffness of the back. One patient had to use crutches for walking. Eight (8%) of 97 patients had a clinically observable swelling.

The mean time between onset of clinical symptoms and determination of diagnosis was 2.0 years (range, 0.1-5.5 years).

Clinical outcome

The mean clinical follow-up after the only or last thermocoagulation was 41 months (range, 5-81 months). Seventy-four (76%) of 97 patients, with a good 95% C.I. of 68% to 85%, had a good response after one thermocoagulation session. Information about relief of pain within 2 weeks of thermocoagulation was complete and could be analyzed in 54 (73%) of 74 patients without recurrent or residual disease. In 47 (87%) of 54 patients post-procedural pain disappeared within one day; it disappeared between 1 and 14 days in the remaining seven (13%). No specific post-procedural policy for pain relief was used; pain medication, such as acetaminophen, was administered according to the needs of each individual patient.

The mean follow-up time in the 74 patients without recurrence was 43 months (range, 5-81 months). This follow-up time was 5-6 months in three (4%) of 74 patients, 7-12 months in 4 (5%) of 74 patients, 13-24 months in 16 (22%) of 74 patients, 25-30 months in 8 (11%) of 74 patients, and more than 36 months in 43 (58%) of 74 patients. Seven (9%) of these 74 patients had minor symptoms that were not attributed to osteoid osteoma. In two of these seven patients mild symptoms resolved spontaneously. One of these two patients had transient limited hip function. In the other patient, symptoms resolved after focal soft-tissue infiltration with 4 mL of a 1% solution of lidocain hydrochloride (Leiden University Medical Center) near the navicular bone in the foot, which was affected by pain and limited function. Three of these seven patients had low back symptoms (persistent mild scoliosis without pain in one and mild pain in the lumbar area of the spine and the iliac crest in two) that did not resemble the symptoms manifested at presentation. One patient each experienced incidental pain in the talus and the lunate bone after abrupt loading or motion.

Twenty-three (24 %) of 97 patients had residual (12 patients) or recurrent (11 patients) symptoms after one thermocoagulation session. Lesions were located in the proximal part of the femur in 10 patients, in the hand in three patients, in the pelvis and the spine in two patients each, and various other locations in the remaining six patients. These 23 patients were followed up for 10 to 68 months (mean, 36 months) after the final treatment (thermocoagulation or surgery). Two (9%) patients were followed up for 10-12 months, seven (30 %) patients were followed up for for 13-24 months, three (13 %) patients were followed up for 25-36 months, and 11 (48%) patients were followed up for more than 36 months.

Postprocedural residual symptoms continued for more than 14 days in 12 (12%) of 97 patients. Nine of these 12 patients had pain, two had pain and impaired function, and one had impaired function without pain. All 12 patients underwent a second thermocoagulation procedure. Ten (83%) of these 12 patients had complete relief of symptoms after this second procedure. The two other patients had residual pain after the second thermocoagulation session, and their lesions were surgically resected. The surgical specimen obtained did not reveal signs of a nidus or other pathologic lesions. Each patient had post-surgical follow-up for 24 and 41 months, respectively, and neither patient had clinical signs of recurrence. One of these patients did have residual and persistent motion-related hip pain that did not resemble the presenting symptoms.

In addition to the 12 patients who had persistent symptoms after the first thermocoagulation session, 11 patients had recurrent pain following a pain-free interval after the first procedure. Five of these eleven patients had associated impaired function. Six of these 11 patients had recurrence of symptoms within 6 months. The mean pain-free period was 10 months, with a range of 1-25 months. In one of these 11 patients recurrent pain was similar, but less severe compared with the symptoms manifested at presentation, and no further treatment was required. The other 10 patients underwent thermocoagulation a second time: five of them had relief of and remained free of symptoms, but the other five again had pain. Three of these five patients continued to have persistent, but less pain after the second thermocoagulation session.

The fourth and fifth patient underwent thermocoagulation a third time. The fourth patient with a lesion in the ulna had recurrent pain 7 months after the first thermocoagulation session, 10 months after the second session and 44 months after the third session. The fifth patient had recurrent symptoms 5 months after the first thermocoagulation session and 8 months after the second session. This patient was free of symptoms 14 months after the third thermocoagulation.

These data can be summarized as follows: when the patients who responded well after the second thermocoagulation were included as good respondents, the number of good respondents increased from 74 (76%) to 89 (92%) of 97 patients, with a 95% C.I. of 86% to 97%.

Histology

In 56 (58%) of 97 patients, material was obtained prior to thermocoagulation to determine a histologic diagnosis. Histology confirmed the presence of an osteoid osteoma in 20 (36%) of 56 patients. In one patient with a 1.5 cm-diameter lesion in the ischium, osteoid osteoma and osteoblastoma could not be differentiated. A histologic diagnosis could not be made in 35 (62%) of 56 cases, because the amount of biopsy material was insufficient.

Complications

In one patient with a tibial lesion, a small area of skin-fat necrosis developed, and this development resulted in a small fistula. The fistula was excised surgically and healed well after excision. This patient was hospitalized for 2 days after fistula excision. In one of the 121 procedures the biopsy needle became fixed in the ischial bone and broke while the physician attempted to mobilize it. The needle was removed surgically, and the thermocoagulation procedure was continued. The patient in whom this complication occurred was hospitalized for 1 day.

All other patients had an uneventful course and were discharged the same day or the morning after the procedure. No neurologic complications were observed after thermocoagulation of spinal lesions. Activities, including sports activities, were not restricted, and crutches or supportive splints or casts were not used.

DISCUSSION

The success rate of 76 % after one session of thermocoagulation (74 of 97 patients, 95% C.I.: 68%, 85%) in our unbiased population was lower than the success rate of 89.5% (34 of 38 patients) reported by Rosenthal et al.(2). Our primary recurrence rate of 24% (23 of 97 patients) was also higher than that reported after percutaneous extraction (six [16%] of 38 patients; mean follow-up, 3.7 years) (10) and surgical resection (0 [0%] of 97 patients) (13). In the study of Rosenthal et al (2), minimal follow-up was 2 years in their 38 patients. It is possible that the coagulation time of 6 minutes used in their study is more effective than the coagulation time of 4 minutes that we used. Another possible explanation for the different success rates is selection of patients. Spinal lesions, for instance, were not reported by Rosenthal et al. In our study all patients, including six with spinal lesions, were treated.

Accurate needle positioning and repositioning in large or non-spherical lesions was also a factor that may have been better handled in the study by Rosenthal et al. When we included second procedures, that were necessary in large or in non-spherical lesions or in technically demanding locations, good results reported by Rosenthal et al. and others (2;11) were within our 95% C.I. of good response; 89 (92%) of 97 patients had good response after one or two sessions with a 95% C.I. of 86% to 97%. Woertler et al (11) reported a success rate of 100% when patients who needed a second session of thermocoagulation were categorized as good respondents.

The relatively low success rate of 50% (five of 10 patients) in the patients who had a symptom free interval after the first session of thermocoagulation is remarkable, in view of the high succes rate of the second thermocoagulation session in patients with persistent pain (10 [83%] of 12 patients). This result adversely affects the overall success rate. The poor results in the small subgroup, with substantially long symptom free intervals, suggest that factors other than residual osteoid osteoma may contribute to recurrent pain. In view of safety and level of invasiveness there is no major disadvantage of two instead of one session of thermocoagulation , especially in patients with persistent pain after the first procedure.

Complications (broken instrumentation and skin necrosis) occurred in only two (2%) of 97 patients who had 121 procedures. Skin necrosis can be avoided by avoiding superficial coagulation close to the skin. Our complication rate is somewhat higher than the rate of 0% (0 of 97 patients) reported by Campanacci et al (13) for surgical resection, but it compares favorably with the complication rate of 24% (nine of 38 patients) reported by Sans et al (10) for percutaneous extraction. Sans et al (10) reported fracture, chronic osteomyelitis, hematoma, skin burns and post-procedural nerve irritation.

The limited level of invasiveness is reflected by the location (i.e., CT room instead of operating theater) in which the procedure was performed and the fact that a hospital stay was not required after the procedure. Patients without complications leave the hospital on the day of the procedure, bear weight bearing immediately, and return to normal daily activity, including sports, without rehabilitation. Obviously, these issues decrease the cost level relative to that of surgical procedures.

The mean hospital stay after percutaneous extraction (10) was 4.8 days, with a range of 2-28 days, and patients were able to bear weight on the affected extremity at a mean of 30 days. The mean hospital stay after surgery (13) was five days, and patients usually resumed normal activity at one to three months after the procedure.

In contrast to the need for medication prior to treatment, no pain medication schedule was needed following successful thermocoagulation. Some patients used acetaminophen occasionally. Pain characteristically disappeared within one day, and, occasionally, it disappeared over several days. All patients with persistent pain after 14 days had additional treatment because of our definition of residual disease.

Our study had several drawbacks. We did not succeed, because of various logistic reasons, which were partially related to the setting of a tertiary referral center, in avoiding missing values in our follow-up data set. Also, we could have prolonged our follow-up time. However, we believed that conclusions could be determined on the basis of information in patients without symptoms after the first thermocoagulation session, with a mean follow-up of 43 months. No less than 52 % (12 of 23 patients) of recurrences were obvious within weeks of treatment; in patients with these recurrences, results after a second session of thermocoagulation were good. Although the majority (six [55%] of 11 patients) of patients in the other group with recurrent pain developed symptoms within 6 months, the range for development of these symptoms was wide, that is, 1-23 months. Despite this wide range in relation to our limited follow-up we concluded that results of repeated thermocoagulation were relatively poor in this specific group.

Another disadvantage of our study was the limited availability of histologic proof. The type of procedure, in part, caused this. We tried to determine a histologic diagnosis only if not all classic clinical and radiologic criteria were present. However, because of small sample sizes related to the kind of procedure performed, a histologic diagnosis could not be made in 62 % (35 of 56) of biopsies performed. We believe that thermocoagulation is a safe procedure in view of our follow-up data, and on the basis of these data, we concluded that there were no recurrent lesions other than osteoid osteoma. Also, no histologic diagnoses other than osteoid osteoma were determined. The possibility that a histologic diagnosis can be determined is an advantage of surgical techniques. When there is serious doubt about the diagnosis of osteoid osteoma, a surgical technique that can facilitate the determination of a histologic diagnosis can be chosen.

The protocol we used to select patients to undergo thermocoagulation of osteoid osteoma consisted of radiography, CT and magnetic resonance (MR) imaging. We used bone scintigraphy to localize the lesion when a clinically suspected lesion was not detected by using radiographs. The value of MR imaging in this regard is still being investigated.

In conclusion, CT-guided percutaneous thermocoagulation is a minimally invasive, safe, and effective procedure for treatment of osteoid osteoma, including spinal lesions. In case of residual symptoms a second thermocoagulation usually is successful in eliminating all symptoms. Results of repeated thermocoaculation in patients who have recurrent symptoms after a symptom-free interval after the first thermocoagulation session are poor.

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Chapter 3

Technical considerations in CT-guided radiofrequency thermal ablation of osteoid osteoma: tricks of the trade

INTRODUCTION

Osteoid osteoma is a benign, slow growing, round or oval lesion of bone with limited growth potential (Fig. 1A). It is characterized by a 'nidus' composed of a variably calcified meshwork of bony trabeculae on a background of fibrous, vascular and nerve tissue (Fig. 1B). The lesion is associated with pain and functional loss. Pain can be severe and is classically worse at night, is relieved by salicylates and disappears following removal or ablation of the nidus (1-4). Osteoid osteomas compose 10% of benign primary bone tumors and are, therefore, not rare in routine musculoskeletal imaging. Children, adolescents and young adults are affected with a male/female ratio of at least 2:1. Most of these lesions arise in or immediately adjacent to a long bone cortex. Half of these lesions occur in the femur or tibia, whereas 10% of all lesions are vertebral (1;3;4).

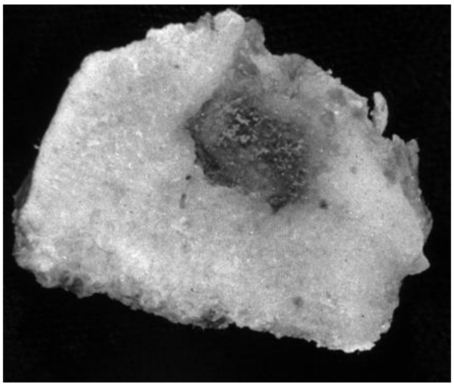
The first report in the literature of technical and clinical success with radiofrequency thermal ablation in the treatment of osteoid osteoma by Rosenthal (5) et al appeared in 1992. This treatment has been performed in our hospital since 1994. Now, a decade later, CT guided radiofrequency thermal ablation has been proven to be an accepted, safe, minimally invasive and cost-effective treatment for osteoid osteoma (5-11). The radiologist's role in the management of this condition has evolved from simply confirming the diagnosis of osteoid osteoma to (along with his or her orthopedic colleagues) to curing the abnormality.

Although this technique is now routinely used in some tertiary referral centers, it could be offered more widely, because in many centers surgery is still routinely performed. This technique could be performed in centers of reasonable size, preferably in those offering a dedicated musculoskeletal imaging service. Radiologists with expertise in bone biopsy or some experience in interventional radiology are ideally suited to learn the procedure. After performing the treatment in approximately 20 patients, the radiologist will have experience in most variations in location and technique. This initial training could be acquired during a formal musculoskeletal or interventional fellowship at a major center offering this treatment, or for a more experienced radiologist, during a mini-fellowship. Thereafter, a steady number of patients per year based on local referral patterns and cooperation with the center's orthopedic surgeons is an important consideration in maintaining skills and justifying the cost of equipment. However, to our knowledge a detailed description of how to perform the procedure, along with technical tips for optimizing outcome and avoiding pitfalls, is still not available in the literature. We recall the steep and long part of the learning curve required to achieve excellent results with this method. For example, some osteoid osteomas by nature of size or location are more difficult to treat and warrant special consideration. Spinal lesions are an area of special interest and concern yet are ideally suited to this technique, sparing the patient and surgeon a difficult and potentially hazardous operation. Furthermore, the diagnosis and management of residual and recurrent lesions can prove problematic.

This perspective will outline the technique of radiofrequency thermal ablation in the treatment of primary and recurrent osteoid osteoma based on our experience of treating nearly 130 patients since 1994 with a success rate of 92% defined by the relief of pain. Our purpose was to educate radiologists considering introducing this form of treatment to their center and to offer suggestions for refinements in technique to those already performing it.

The Principle of Thermocoagulation

Radiofrequency thermal ablation is a form of electrosurgery in which an alternating current of high-frequency radiowaves (>10 kHz) passes from an electrode tip in body tissue and dissipates its energy as heat. A radiofrequency generator forms an electric current that flows from the generator, through the electrode into the patient, and out through a



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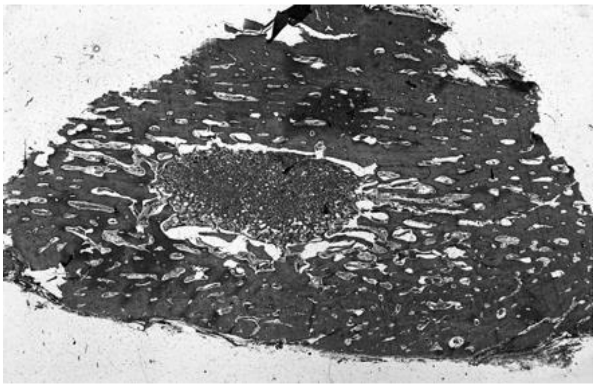

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Figure 1
Osteoid osteoma
A, Photograph of gross specimen of en bloc resection shows nidus in sclerotic host bone.
B, Photomicrograph of histologic section shows nidus surrounded by dense reactive cortical bone. (H and E, x10)

grounding electrode or pad back to the generator. Resistance of biologic structures causes local ions to vibrate. This ionic agitation results in friction around the electrode tip as ions attempt to pursue changes in direction of the alternating current and create heat to the point of dessication – hence the term thermal ablation (12;13). Radiofrequency thermal ablation differs from electrocautery in that the tissue around the electrode, rather than the electrode itself, is the primary source of heat (Fig. 2).

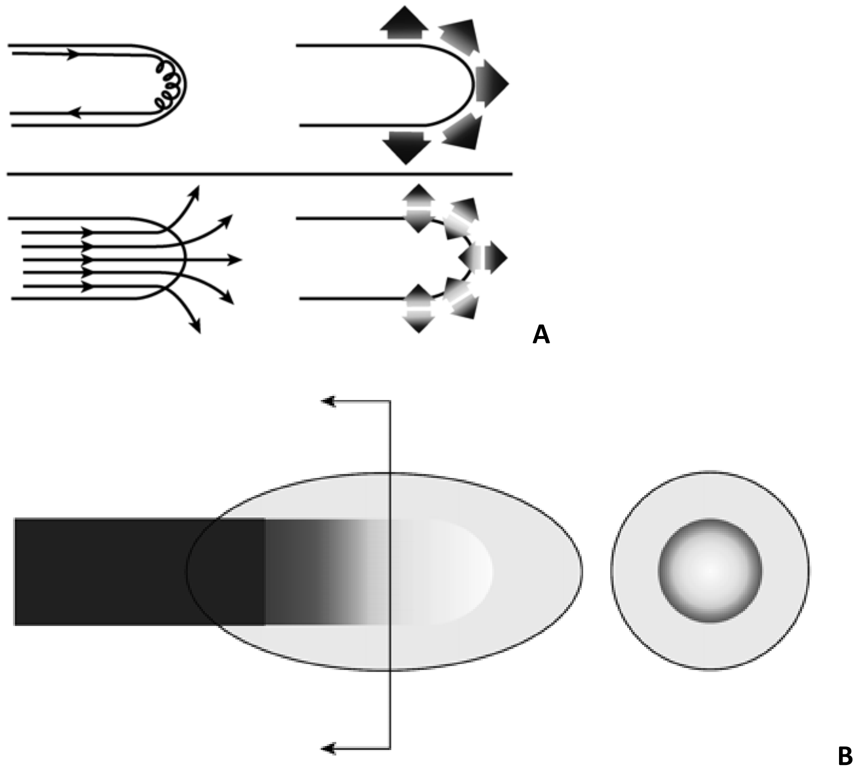

Figure 2
Principles of radiofrequency thermal ablation. (Adapted with permission from (13))
A, Drawing shows difference in current flow and heat flow in electrocautery with current through heater element in probe resulting in heat flow from probe to tissue (*top*) and radiofrequency thermal ablation with current flow into tissue resulting in heat flow from tissue to probe (*bottom*).
B, Drawing shows side and front views of radiofrequency thermal ablation treatment zone, which is a spherical ellipse centered on non-insulated portion of electrode tip.

To perform radiofrequency thermal ablation successfully, one must understand the concept of a ‘treatment zone’, which may be defined as the amount of tissue ablated. The maximum size of the treatment zone may be predicted by the following equations:

1. long axis of treatment zone = 2 x length of bare tip
2. transverse axis = 2/3 long axis (13)

For an non-insulated electrode tip length of 5 mm, there is an approximately 1 cm spherical treatment zone of focal osteonecrosis (5;14;15).

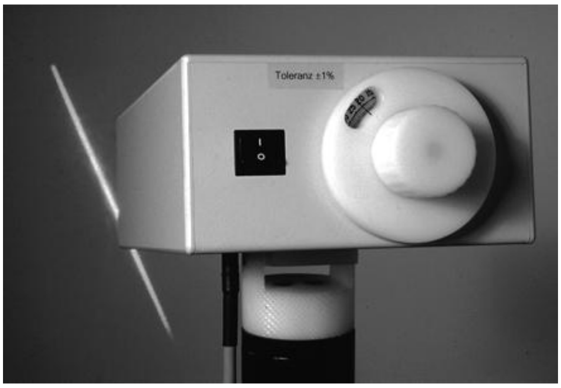

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Figure 3
Equipment used in radiofrequency thermal ablation.
A, Photograph shows laser goniometer that allows targeting of laser beam to be set at any degree of angulation.
B, Photograph shows that laser beam reflects on needle to ensure correct angulation.

MATERIALS AND METHODS

Indications

CT-guided radiofrequency thermal ablation should be attempted only when a definite nidus is identified on CT in a patient with an appropriate history suggestive of osteoid osteoma (9). The target tissue is the nidus. Strict criteria comprising visualization of a distinct radiolucent, round or oval nidus with variable internal calcification on fine-section CT (slice thickness, 1-3mm) should be applied. This will avoid the risk of ablating lesions that may mimic an osteoid osteoma such as a Brodie's abscess or geode, for which an alternative therapy or no treatment is required.

Equipment

CT guidance affords the best available visualization of needle and probe placement within the lesion nidus. Helical CT with low-dose, "quick-check" CT fluoroscopy results in savings of time and dose for the patient (16;17). A general anesthetic allows a pain-free procedure and absolutely stable patient position, although spinal anesthesia is an option for lower limb lesions. Early in our experience, local anesthetic proved unsuccessful because of inadequate pain control in spite of adequate anesthetic infiltration in soft tissue and overlying periosteum. Entering the nidus itself elicits extreme pain in most cases resulting in patient movement and loss of position. The time required for the procedure is typically 90 minutes, including the time until the patient is stable under anesthesia.

For most patients with limb lesions, supine positioning is ideal because it affords good access and is the best position for administration of a general anesthetic. The limb may be internally or externally rotated and secured with tape or straps to allow good skin access, easier needle placement and avoidance of neurovascular structures. Spinal lesions are treated with the patient lying prone with a padded ring beneath the chest for easier ventilation. A laser goniometer (Targo-Beam; Vasculab Medizintechnik, Wismar, Germany) can help guide accurate, first-time needle placement (Fig. 3).

We use the Bonopty coaxial bone biopsy system (Radi Medical Systems, Uppsala, Sweden) for lesion access. The system's small-caliber needles and multicapability components such as drill and biopsy cannula make it ideally suited for radiofrequency thermal ablation. The system comprises a 95-mm-long 14-gauge (2.1 mm) Bonopty Penetration cannula, a 100-mm-long 15-gauge (1.7 mm) Bonopty Drill, a 160-mm-long 15-gauge (1.7 mm) Bonopty Extended Drill and the 160-mm-long 15-gauge (1.7 mm) Bonopty Biopsy cannula. The radiofrequency thermal ablation probe (SMK-TC15, Radionics, Burlington, MA) is a 15-cm-long, straight, rigid electrode with a diameter of 1 mm. An incorporated temperature-measuring device (thermistor) allows precise monitoring of the probe tip temperature. The probe is introduced via a 145-mm-long dedicated Sluyter-Mehta 20-gauge thermal ablation cannula with a 5-mm-long non-insulated tip (Radionics). The 20-gauge thermal ablation cannula is placed through the bone-penetration cannula at the time of treatment.

The radiofrequency thermal ablation probe is connected to a radiofrequency generator (Radionics-RFG 3C RF-Lesion Generator System) which supplies the monopolar radiofrequency current. The device delivers an alternating current (AC) of approximately 500 kHz in a continuous unmodulated sinusoidal waveform when in “lesion” mode.

Grounding

Grounding consists of a dispersive electrode placed close to the lesion site to draw current back to the radiofrequency unit. A large-area adhesive-gel grounding pad like that used in the operating room has the advantages of no skin penetration and reduced current density, resulting in less heating at the dispersive electrode to avoid tissue burns at this site (Fig. 4A).

Contraindications

The radiofrequency generator can cause unwanted physiologic effects; therefore, this technique is contraindicated in patients with cardiac pacemakers. Anesthetic-monitoring equipment has not caused a problem in our group of patients to date, although experience is limited at this stage.

Potential Complications

Although this technique is minimally invasive, potential complications which may occur during needle passage include bleeding and nerve injury. These can be avoided by knowledge of anatomic structures in the region of needle passage and an alteration in the approach to avoid neurovascular bundles. Soft-tissue burns, especially skin burns, are a further possible complication. There is a higher risk of skin necrosis in osteoid osteomas in superficially located bone, in which extra care is required. This complication is avoided by withdrawing the outer cannula to approximately 1 cm above the non-insulated tip of the coagulation cannula. In spite of this precaution, we had one skin burn complication in a patient with an anterior tibial osteoid osteoma, with subsequent development of a subcutaneous fistula to the skin, requiring surgical débridement. The most likely explanation is a defect in the insulation material covering the thermal ablation cannula that was not confirmed as the cannula had been discarded immediately after the procedure. A quick visual check of the insulation material to avoid this rare occurrence is advised.

Informed Consent

Formal informed consent is obtained before the procedure and should include an outline of the procedure with specific mention of the low risk of potential complications as described previously. We specifically state that a second treatment may be required in the unlikely event that there are residual or recurrent symptoms. For osteoid osteomas close to joints, especially in the hand or foot, the patient should be warned that damage to articular cartilage is a possibility, which may predispose to early degenerative arthritis. However, this should be balanced by the fact that operative treatment is potentially even more damaging. The patient should be advised that after treatment, pain may be transiently increased for 24-48 hours, for which a moderate-strength oral analgesic may be required. Informed consent for a general anesthetic is obtained from the patient by the anesthesiologist on the day of treatment.

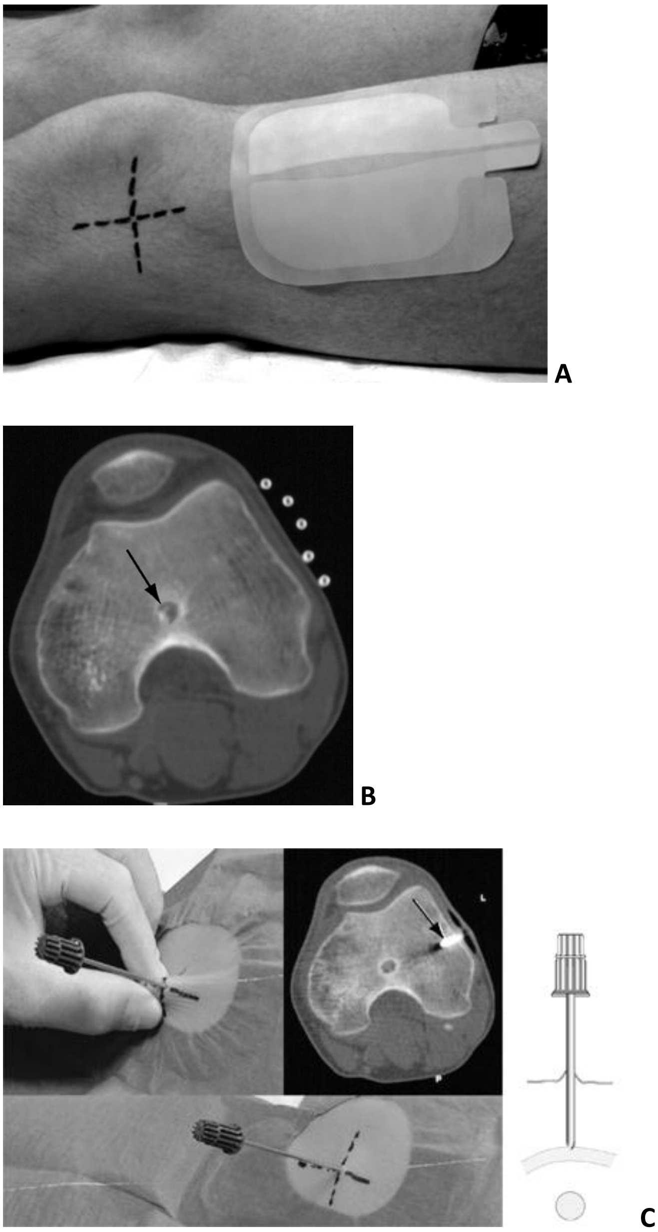


Figure 4

Step-by-step technique of radiofrequency thermal ablation of osteoid osteoma in left distal femur of 20-year-old man.

A, Photograph shows that grounding pad is placed close to marked skin entry point for shortest current path.

B, Axial CT scan shows markers (*white circles*) for planning skin entry point and radiolucent nidus with sclerotic margin (*arrow*).

C, Photograph shows bone-penetration cannula inserted through bone cortex (*arrow*). Note corresponding CT scan and drawing of cannula's insertion.

TECHNIQUE

The method we use and our rationale may be summarized in the following eight relatively simple steps. Incorporated in these descriptions and the accompanying figures are tips to ensure a smoother procedure and to assist the reader in more difficult situations.

Eight Steps

Step 1, localization and planning.

From a 3- to 4-cm block of 1-mm thick slices, the precise lesion size is determined. For osteoid osteoma of less than 1cm, a single, central skin entry point is planned, and the table position noted. For a lesion greater than 1 cm, more than one probe position must be planned because of the limited size of the treatment zone. The best approach is then chosen and the angle of inclination measured (a 90° true vertical approach is often easiest but not always possible near vital structures). The aim is to puncture in the scan plane; planning an entry point perpendicular to the bone surface will help to avoid needle slippage (Fig. 4B). Safe anatomic safe entrance is sometimes through the opposite, normal cortex. This allows avoidance of neurovascular structures and joints without drilling through added amounts of hard, reactive bone.

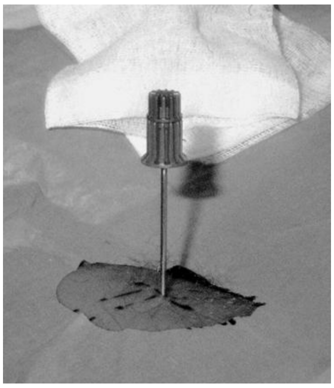
Step 2, grounding pad.

The grounding pad should be placed close to the planned skin entry point to allow the shortest current path through the patient (Fig. 4A). The area is then sterilized and draped.

Step 3, superficial bone entry with use of tenting.

A 2-mm skin incision is made and the penetration cannula with stylet is then inserted through the soft tissues and into the bone surface (Fig. 4C). If the needle tip slips at this stage, the skin and underlying tissues around the cannula can be gathered up with a pinchlike maneuver to form a “tent”. While the operator exerts forward force on the cannula against bone, the soft tissues are lifted partway over the shaft to enable better purchase for


D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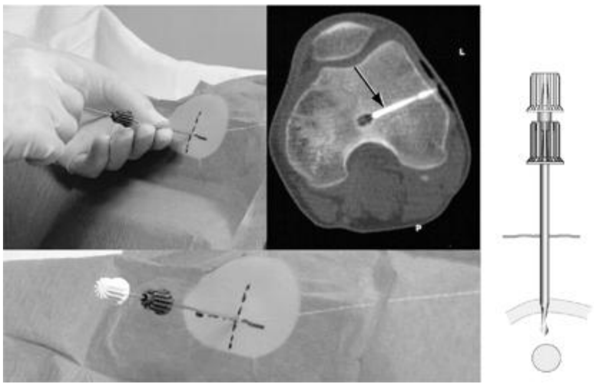
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Figure 4 (continued)
Step-by-step technique of radiofrequency thermal ablation of osteoid osteoma in left distal femur of 20-year-old man.
D, Photograph shows “tenting, a technique used to overcome displacement of needle tip by drawing skin over needle shaft.
E, Photograph shows stable needle position after tenting.
F, Photograph shows that drill (*arrow*) is inserted through bone penetration cannula. Note corresponding CT scan and drawing of drill position.

bone entry. This technique of tenting minimizes the tendency of gravity, overlying muscles and other elastic tissues to displace the needle tip (Figs. 4D and 4E).

Step 4, drilling and milling

The inner stylet is exchanged for the drill (when needed for deeper lesions), and drilling to the edge of the nidus is performed (Fig. 4F). During drilling, position and direction are verified with further scans. The drill has an eccentric mechanism, which creates a larger hole than the actual drill diameter; however when no progress is made in dense bone, the drill can be carefully removed and cleaned. If a slightly wayward direction occurs, the edge of the channel can be “milled” by angulating the drill with forward pressure towards the lesion. The penetration cannula is carefully advanced over the drill so that it sits at least in bone cortex, and the drill is then removed. The penetration cannula is held firmly against the bone during exchange to maintain a stable position. The anchored penetration cannula now serves as a fixed pathway for biopsy and radiofrequency thermal ablation.

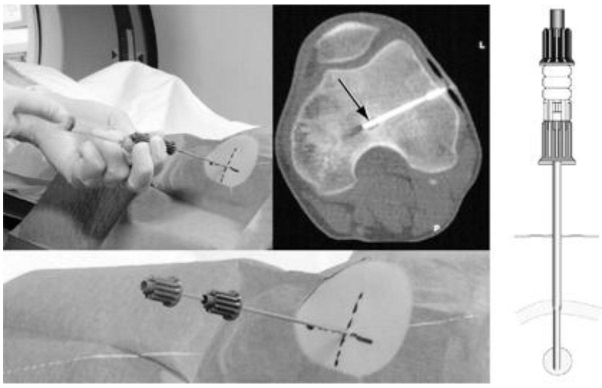
Step 5, biopsy.

Although biopsy is optional because the decision to treat has typically been made before the procedure, we perform it routinely for histologic confirmation of the diagnosis that may prove helpful in cases of residual or recurrent symptoms.

The biopsy cannula is inserted through the penetration cannula, and the biopsy specimen is removed by using gentle suction (Fig. 4G). Tissue material, fixed in formalin, is sent for histology. Appropriate decalcification is mandatory before embedding and cutting slides. In confusing clinical presentations, material is also occasionally sent for microbiologic examination.

Step 6, cannula and probe placement.

The thermal ablation cannula with a stylet is next inserted through the bone-penetration cannula, and a check scan is made. Generally, the thermal ablation cannula tip should lie in the center of the lesion. Control scans of 2 mm in thickness are made 5 mm



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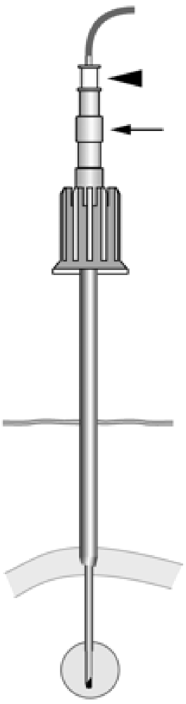

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Figure 4 (continued)
Step-by-step technique of radiofrequency thermal ablation of osteoid osteoma in left distal femur of 20-year-old man.
G, Photograph shows biopsy and use of suction. Note corresponding CT scan (*arrow*) and drawing of biopsy probe tip (arrow) in nidus.
H, Drawing shows thermal ablation probe (*arrowhead*) and thermal ablation cannula (*arrow*) inserted through bone-penetration cannula into nidus.

cranial and 5 mm caudal to the thermal ablation cannula tip position. If the osteoid osteoma nidus is contained within these limits, then the position is satisfactory. Thicker control scans make it easier to demonstrate the lesion, but are less accurate for positioning (Rosenthal DI, personal communcication). The radiofrequency thermal ablation probe (the tip protrudes slightly) replaces the stylet, which is removed (Fig. 4H). The penetration cannula is then withdrawn slightly so that its tip is at least 1 cm above the bare tip of the thermal ablation cannula. This will prevent the current contacting the penetration cannula and resulting in undesired tissue burns or loss of current. A final check scan is obtained to ensure that there is no loss of position during the exchange of the thermal ablation probe for the stylet or on withdrawal of the bone-penetration cannula tip.

If the lesion extends beyond the outer confines stated above, there is no guarantee that the entire lesion will be ablated. A second ablation must then be planned in the same session to ensure that the thermal ablation cannula tip is within 5 mm of the inner edge of the nidus to ensure incorporation in the treatment zone and adequate ablation. A second ablation position can often be achieved through the first access hole by angulating the penetration cannula and milling the edge of the hole with the drill to the desired position. This procedure will require check scans outside the previous scan plane.

Step 7, electrode connection.

To avoid any effects of galvanic potentials or static electricity, the radiologist must first attach the dispersive electrode cord to the grounding pad by an alligator clip and plug it into the reference jack on the radiofrequency generator. The radiofrequency thermal ablation probe may then be connected (this can be done by the assistant to enable the primary operator to remain sterile). A further check scan at this point is not usually required unless the patient moves excessively during the connection maneuver. The radiofrequency generator is switched on, and electrical impedance is measured. Expected tissue resistance is 200-600 ohms, which confirms an adequate circuit. When a higher value is recorded, the thermal ablation probe and cannula should be checked for external damage. If tissue resistance exceeds 1000 ohms and is associated with increased current requirement, there is an inadequate circuit. The temperature at the tip of the thermal ablation probe is the guide to assessing the current requirement; an increased current requirement is defined by the need to excessively increase the current output to achieve the desired temperature of 90°C. In this situation, the possible causes of an increased requirement include an equipment fault or more commonly a “dry tip” with poor electrical coupling. Removing the thermal ablation probe and flushing the thermal ablation cannula with 1 mL of 0.9% saline should improve electrical conductivity and current flow and correct resistance values.

Step 8, Radiofrequency thermal ablation: 90°C for 4 minutes.

The automatic temperature override control is set to 93°C (the maximum desired temperature). Built-in circuitry will prevent the lesion temperature from exceeding the set value. Radiofrequency thermal ablation is performed by smoothly turning the output control knob for 30-60 seconds until the desired temperature of 90°C is displayed. The lesion time control is set to its maximum of 2 minutes, then repeated (total time, 4 minutes). Rosenthal et al. (9), who began using an ablation time of 4 minutes, now prefer 6 minutes because patients were experiencing a number of recurrences (5;9). However, Rosenthal concedes that there is probably little scientific rationale for this change because his group’s original experiments had shown that a steady state is reached with little change in treatment-zone size after approximately 3 minutes (Rosenthal DI, personal communication). We are satisfied with our present protocol of 4 minutes ablation time. During ablation, the output control button should be adjusted up or down to ensure a stable lesion temperature of 90°C (down regulation of current load is most commonly necessary) (5). If a second ablation is required, the bone-penetration cannula can be repositioned through a separate skin incision if necessary. The previous steps are repeated to ensure ablation of the entire lesion.

Current intensity

Current intensity is one of the most important variables influencing the size of the treatment zone. A lack of appreciation of the size of the treatment zone relative to the size of the osteoid osteoma to be ablated may result in failure to treat the entire lesion and inevitable residual or recurrent symptoms. Appropriately applied current will result in a treatment zone of predicted and desired size. The current is too low when the temperature at the tip fails to reach 90°C for the 4 minute duration of treatment, producing an under-size

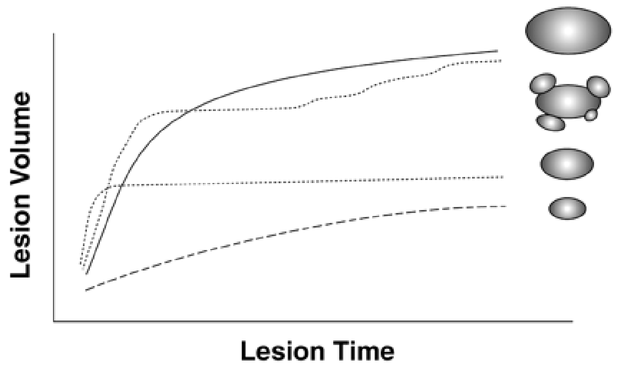


Figure 5
Graph shows treatment-zone volume as function of current intensity. (Adapted with permission from (13))
Adjacent drawings depict relative size and configuration of treatment zone with adequate current (*solid line*), current too high or applied to rapidly (*dotted lines*) and low current (*broken line*).

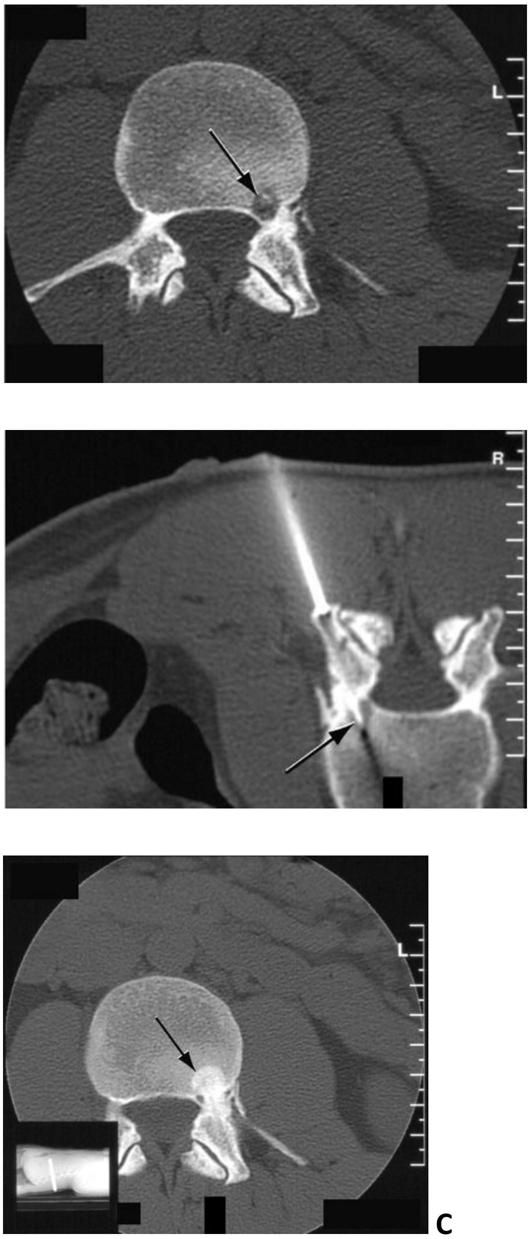
zone. If the current is too high or is applied too rapidly, heating may be so intense that solidification and charring limit further current flow. These effects results in a suboptimally small treatment zone. Charring manifests as an abrupt fall in current with a voltage rise due to increased tissue resistance. Alternatively, areas of vaporization can result in an irregular-shaped zone that may be larger in parts, but with other areas that are not ablated (13) (Fig. 5). The technique advocated in this article uses a non-cooled electrode tip that restricts the size of the treatment zone but has the advantage of precise tissue destruction encompassing the nidus itself, with minimal damage to normal adjacent bone. The non-cooled tip is ideal for most osteoid osteomas. Cooled tips such as those used in radiofrequency thermal ablation of various liver lesions involve the use of an infusion of cool saline through the electrode, which has the advantage of allowing greater heat transmission with higher currents to create larger treatment zones. However, the size of the treatment zone is also not completely predictable with a cooled tip (Rosenthal DI, personal communication). Although larger treatment zones would occasionally be desirable in treating some osteoid osteomas to avoid multiple probe placements, we prefer the non-cooled tip to have an entirely predictable treatment zone size and thus to minimize damage to adjacent non-lesion tissue.

Physiological Reaction to Radiofrequency Thermal Ablation

Despite the use of general anesthetic, in about 50% of patients we have observed a physiological reaction to entering the nidus or during ablation. This reaction consists of variable increases in blood pressure, heart rate and respiratory rate. The patient may even move and cause a loss of position. The reaction subsequently normalizes when the lesion is completely destroyed and seems compatible with theories suggesting a neurogenic origin for the pain associated with an osteoid osteoma (18-20). We routinely ask our anesthetist to look for this reaction, as it is useful confirmation that we have entered a nidus.

Postprocedure and Bone Healing

Pain is variable after radiofrequency thermal ablation. Some patients report pain for up to 1 or 2 days after the procedure. This typically settles quickly and analgesia is rarely required. A clinical check is made prior to discharge (usually the same day as the procedure). Patients may weight bear immediately and return to normal activities (including sports).



A B C

Figure 6
22-year old man with osteoid osteoma of junction body and left pedicle L3 vertebra.
A and B, Axial CT scans show classic radiolucent nidus with fleck of calcification (*arrow,* A) and radiofrequency thermal ablation probe in situ (*arrow,* B) during treatment.
C, Axial CT scan obtained 1 year after treatment shows filling in with sclerosis (*arrow*).

Follow-up clinical assessment is made at 2 weeks. At this time, patients with persistent pain requiring a second thermal ablation can be identified. Patients who experience recurrent pain after a period of immediate pain relief can be identified either by instructing the patient to come back or by using a standard follow-up scheme with an increasing interval. Ultimately, resolution of pain is the primary parameter used to define a successful treatment.

Radiographically, partial or complete infilling of the nidus with sclerotic bone (Fig. 6) is expected over 2-27 months, although little or no change in lesion appearance is also possible. Eventually the nidus site can become indistinguishable from surrounding bone, and reactive changes in adjacent bone and periosteum also tend to diminish.

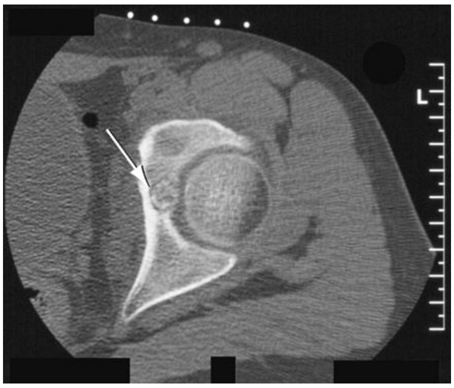
SPECIAL CONSIDERATIONS

Certain lesions by nature of their anatomic location or enlarged size warrant special consideration. Compared with a relatively straightforward technique in most limb osteoid osteomas, these groups require an added degree of planning. This section outlines such lesions and provides tips to help ensure an optimal outcome.

Spinal Lesions

Spinal lesions comprise 10% of cases of osteoid osteoma. Most lesions will occur in the lumbar spine (59%) followed by the cervical (27%), thoracic (12%) and sacral regions (2%) (1;3;4). Lesions are almost always in the posterior elements and are located in the pedicles (75%), laminae, articular processes and only uncommonly occur in the vertebral body. More important, for this form of treatment, lesions do not usually involve the spinal canal or paraspinal tissues.

The technique used for spinal lesions is essentially the same as for any other site. The patient is placed prone and a posterior approach used (Fig. 6). For most lesions in the posterior elements, ablation should be straightforward. Pedicle or posterior vertebral body lesions will require considerably more drilling, analogous to routine bone biopsy at these sites. Care should be taken to avoid entering a facet joint or neural foramen. When no complete shelf of protective bone surrounds a lesion, thermal injury to neural or vascular



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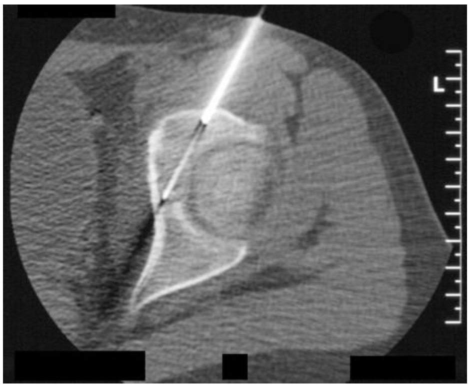

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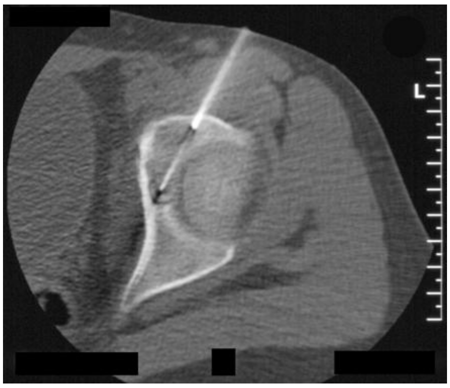

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Figure 7
15-year-old boy with 1.5cm osteoid osteoma of left acetabulum, requiring multiple ablation positions.
A-C, Axial CT scan shows partly calcified nidus (*arrow,* A), deep probe position (B), and superficial probe position (C). White dots (A) are skin markers.

structures may occur. We have not had to treat such a lesion to date; however, Dupuy et al. (21) successfully treated an intraspinal osteoid osteoma of 1 cm sited at the junction of the T11 right pedicle and lamina which abutted the thecal sac with no ill effects. These same researchers measured temperature changes in the adjacent spinal canal while applying radiofrequency to pig vertebral bodies. No cytotoxic temperature elevations were recorded in the spinal canal (21).

In an ex-vivo study reported in the same article (21), the authors confirmed that there is decreased heat transmission in cancellous and cortical bone. They raised the possibility that local heat sinks due to the presence of the rich epidural venous plexus and cerebrospinal fluid pulsation may also be factors.

For most spinal osteoid osteomas, radiofrequency thermal ablation is a safe and effective alternative to medical management and preferable to surgery. As mentioned by Dupuy et al. (21) and in spite of their success in one case, this technique may be contraindicated when no intact cortex is evident between the nidus and the spinal cord or nerve root.

Large Lesions

For osteoid osteomas larger than 1 cm in any dimension, radiofrequency thermal ablation must be performed at more than one probe position, preferably with overlap of the treatment zones. Large cancellous bone osteoid osteomas are more likely to be round; therefore, we place the probe in two access tracts in a craniocaudal direction. In each tract we perform the ablation in two separate positions, superficial and deep (four positions and a 16-min ablation) (Fig. 7). Large cortical osteoid osteomas in the long bones tend to be elongated and may exceed 1 cm in length in a craniocaudal direction. New multidetector CT scanners with fast multiplanar reconstructions may aid planning by allowing assessment of the precise lesion configuration at the time of treatment (Fig. 8).

Lesions Close to Joints

The hip joint is involved much more commonly than the elbow, wrist, knee and foot. Avoiding a transarticular approach will minimize the small risk of introducing infection, negate cooling effects from any associated joint effusion, and also reduce the chance of inadvertent ablation of articular cartilage. For acetabular lesions needle passage through the

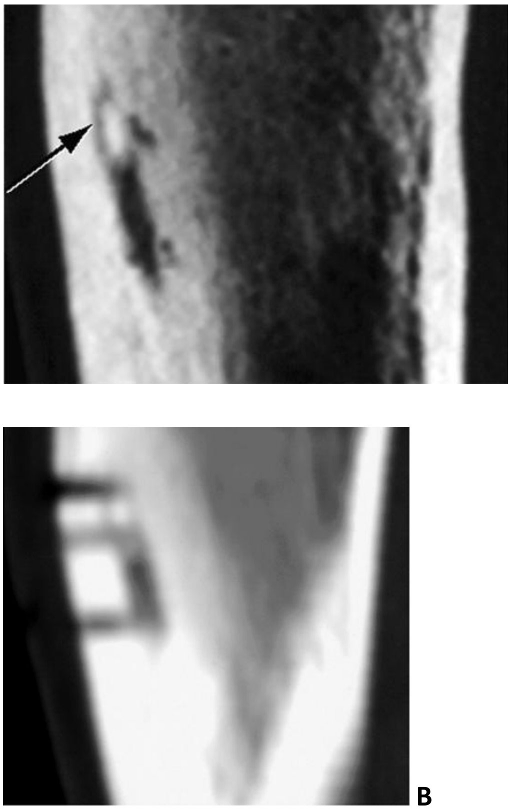


Figure 8
Multidetector CT scans of 1.8 cm long recurrent osteoid osteoma of right anterior tibia in 14-year-old boy.
A, Sagittal multiplanar CT reconstruction shows long radiolucent nidus with calcification superiorly (*arrow*).
B, CT scan with sagittal reconstruction after procedure shows three approach holes used for overlapping ablation.

hip joint is usually not required. For lesions of the anterior proximal femoral neck, joint passage is occasionally required, however we have encountered no complication in the few cases in which it was necessary. Internally rotating the lower limb provides easier access (perpendicular to the cortex) to lesions of the anterior proximal femoral neck by an anterior approach. The femoral neurovascular bundle is usually easy to avoid. For posterior proximal femoral neck lesions, we generally also use an anterior approach. For lesions close to small joints, particularly in the carpus or tarsus, some degree of articular cartilage damage is inevitable (as would occur in surgery), and this should be discussed with the patient at the time of obtaining consent.

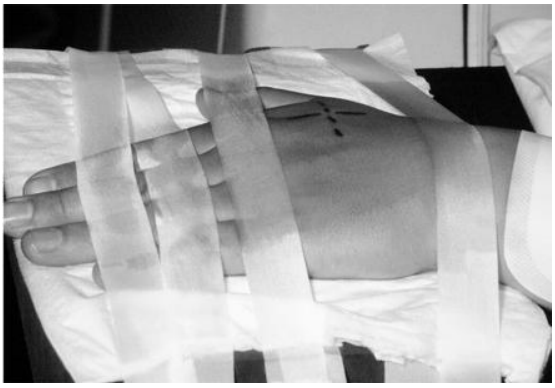
Figure 9
Coronal T1-weighted MR image of technique demonstration case, a rare epiphyseal osteoid osteoma in 21-year-old man. Angulated approach is superimposed (*dotted line*).

Lesions Adjacent to Open Growth Plates

A cranially or caudally angulated approach in these rare cases reduces the risk of damaging the undulating growth plate (Fig. 9).

Superficial Lesions

A dorsal approach for most carpal-metacarpal and tarsal-metatarsal lesions protects the important volar structures (Fig. 10A). After placement of the thermal ablation probe, we withdraw the bone-penetration cannula to above the level of the skin to negate the risk of contact with the active tip and thus avoid skin burns (Fig. 10B). The minimal distance for safety from the tip of the bone penetration cannula to the skin is 1 cm. The outer cannula can be taped to the thermal ablation cannula with sterile tape, or, if this is not possible, removed entirely. The thermal ablation cannula is then reinserted through the skin and drill hole followed by the thermal ablation probe.



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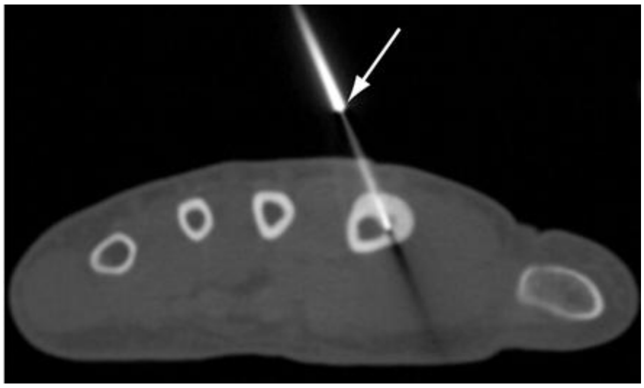

B

Figure 10
18-year-old man with osteoid osteoma of left index finger metacarpal.
A, Photograph shows hand position with skin marking for dorsal approach to protect volar structures.
B, CT scan shows thermal ablation probe in situ in nidus. Note bone-penetration cannula withdrawn to above skin to avoid risk of skin burn. Arrow indicates tip of bone-penetration cannula.

Diagnosis and Management of Residual and Recurrent Symptoms

Residual symptoms may be defined as pain or impaired function or both, identical to or resembling the presenting complaints, that persist for more than 2 weeks after radiofrequency thermal ablation. Recurrent symptoms are defined as the reappearance of symptoms that follow a symptom-free period after radiofrequency thermal ablation.

Patients with residual and recurrent symptoms will usually benefit from a second ablation of the apparently incompletely treated nidus. Remnant areas of viable lesion persist peripherally in round lesions or at one or both ends of elongated lesions. We repeat the

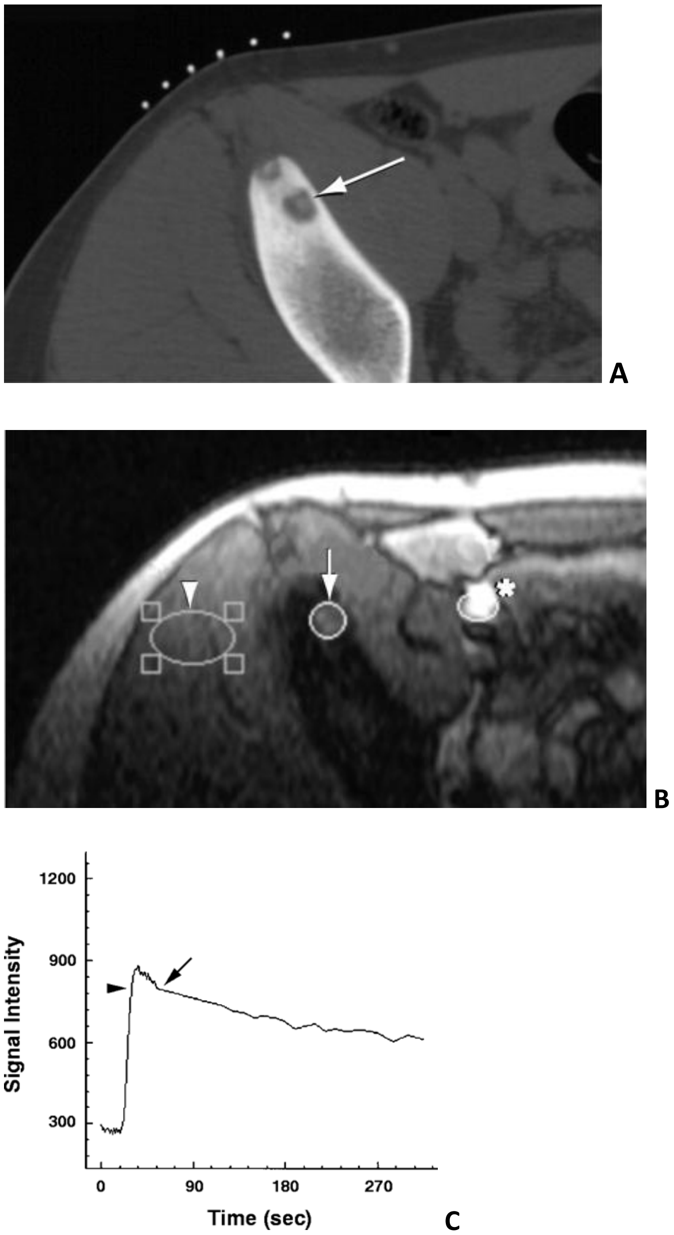

Figure 11

Primary osteoid osteoma of right anterior iliac crest in 14-year-old boy.
A, Axial CT scan shows radiolucent nidus (*arrow*). White dots are skin markers.
B, Axial gadolinium-enhanced gradient-echo MR image shows region of interest on adjacent muscle (*arrowhead*), osteoid osteoma (*arrow*) and artery (*asterisk*).
C, Dynamic contrast-enhanced MR imaging signal intensity versus time curve shows typical active osteoid osteoma dynamic enhancement profile of steep upslope (*arrowhead*) and down-slope (*arrow*), indicating rapid contrast accumulation in nidus followed by washout.

initial imaging protocol when symptoms are present, and we have found that plain radiographs and limited-section CT are often sufficient. Radiological confirmation depends on the timing of recurrent symptoms - the longer the interval, the more the sclerosis is seen at the ablation site on CT. Lesion radiolucency stands out, giving a good target for a repeat procedure. Dynamic contrast-enhanced CT or MR imaging can help when mixed areas of radiolucency and sclerosis on CT make it difficult to determine the precise location of the recurrence. Rapid enhancement within 3-6 seconds after arterial enhancement, followed by rapid washout in our experience and that of and Von Kalle et al. (Von Kalle T et al., presented at the International Pediatric Radiology meeting, May 2001), is indicative of the presence of viable lesion tissue (Fig. 11).

Two or more probe placements may be required for the follow-up radiofrequency thermal ablation, which can be expected to result in a cure. If symptoms persist but the lesion continues to look like an osteoid osteoma, a third ablation can be attempted. However if the lesion now appears atypical, surgical excision is probably warranted when feasible. The initial treatment using this technique is based on clinical and radiological proof. Although a definitive histologic diagnosis is not required, confirmatory information can be helpful in guiding further management in case of residual or recurrent symptoms.

CONCLUSION

Osteoid osteoma is a benign lesion of bone affecting a young person and causing pain and functional loss. CT-guided radiofrequency thermal ablation is a safe, minimally invasive and effective treatment (5-11). Accurate measurement of lesion size is critical and more than one ablation position may be required. Radiofrequency thermal ablation at 90°C for 4 minutes at each position is usually adequate to effect a cure.

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Chapter 4

Osteoid osteoma: factors that increase the risk for unsuccessful thermal coagulation of osteoid osteoma

ABSTRACT

Purpose: To retrospectively identify risk factors that may impede a favourable clinical outcome after thermocoagulation of osteoid osteoma.

Material and Methods: Informed consent (permission for the procedure and permission to use patient data for analysis) was obtained from all patients who met study criteria, and institutional review board did not require approval. Analysis included age, sex, size and location of osteoid osteoma, presence of calcified nidus, number of needle positions used for coagulation, coagulation time, accuracy of needle position, learning curve of radiologist, and previous treatment in 95 consecutive patients with osteoid osteoma treated with thermocoagulation. With chi-square analysis, Fisher exact test or unpaired Student *t* test and logistic regression analysis 23 unsuccessfully treated patients were compared with 72 successfully (pain free) treated patients.

Results: Parameters associated with decreased risk for treatment failure were advanced age (mean age, 24 years in treatment success group *vs* 20 years in treatment failure group) and increased number of needle positions during thermocoagulation. Estimated odds ratios were respectively 0.93 (95% confidence interval: 0.88, 0.99) and 0.10 (95% confidence interval: 0.02, 0.41). Patients with a lesion of 10 mm or larger seemed at risk for treatment failure (odds ratio = 2.68); but the 95 % confidence interval of 0.84 to 8.52 included the 1.00 value. Needle position was inaccurate in nine of 23 patients with treatment failure; only one needle position was used in eight of these nine patients. Lesion location, calcification, sex, coagulation time, radiologist’s learning curve and previous treatment were not risk factors.

Conclusion: Multiple needle positions reduce the risk of treatment failure in all patients and should especially, but not exclusively, be used in large (≥ 10 mm) lesions or lesions that are difficult to engage to reduce the risk for unsuccessful treatment.

INTRODUCTION

Osteoid osteoma is a benign condition with a characteristic clinical and radiologic presentation that allows identification of patients, without making a histological diagnosis, who benefit from thermocoagulation with immediate relief from symptoms (1-10). We previously reported the clinical outcome in an unselected group of consecutive patients (both successfully and unsuccessfully treated patients) (11). At that time, however, we did not analyze the factors that may have affected the clinical outcome in that group of patients. Thus, the purpose of our current study was to retrospectively identify risk factors that may impede a favorable clinical outcome after thermocoagulation of osteoid osteoma.

MATERIALS AND METHODS

Patients

All 110 consecutive patients with an osteoid osteoma treated with thermocoagulation between June 1994 and April 2000 were eligible for inclusion in this study. Exclusion criteria for this analysis were: incomplete imaging or clinical data set, and a follow-up shorter than 3 months (arbitrarily chosen). Ninety-five patients were included in this analysis, and 15 patients were excluded: nine who were free of symptoms because follow-up was shorter than 3 months, and six, because data were incomplete. Nine (9 %) of 95 patients previously underwent surgery at the referring hospital before they were treated with thermocoagulation at our hospital. One patient was previously treated with thermocoagulation elsewhere, but this procedure had failed because of technical reasons. The mean age of the 95 included patients was 23 years (range, 4-53 years). The male-female ratio was 2.8. The mean age of the 70 male patients was 22.8 years (range, 4-53 years), and the mean age of the 25 female patients was 23.2 years (range 4-52 years). Informed consent (permission for the procedure and permission to use patient data for analysis) was obtained from all patients who met our criteria or from parents of children who did. Our institutional review board did not require its approval for this study.

Lesion Diagnosis and Location

Clinical and imaging criteria (radiographs and computed tomographic [CT] scans) used to establish a diagnosis of osteoid osteoma at the time of inclusion are described elsewhere (3;5;11). Typically patients have pain (nocturnal) that is not related to physical activity and is not relieved or alleviated by salicylates or other nonsteroidal antiinflammatory drugs. Radiographs and CT scans display a nidus that may be radiolucent or calcified and, characteristically, the maximal diameter does not exceed 1.5 cm, with surrounding reactive sclerosis and periosteal reaction. Initially an imaging diagnosis of osteoid osteoma was established in consensus (W.R.O., G.M.V.) in all 95 patients. A biopsy was performed when the radiologic findings and clinical presentation were not completely typical. In 40 patients, all criteria mentioned previously were met, and biopsy specimens were not removed. In the remaining 55 patients we attempted to obtain a histologic diagnosis by removing a biopsy specimen immediately prior to thermocoagulation. A histologic diagnosis of osteoid osteoma was determined in 20 of these 55 biopsies. No histologic diagnosis could be determined in the remaining 35 patients because of insufficient material.

The same two authors reviewed cases in these 35 patients to identify reasons why the cases were considered to be atypical at the time of treatment. Cases in nine of the 35 patients turned out to be typical after all, although lesions in seven of these were found in uncommon locations such as the ulna, the humerus (two patients), the carpal bone, the lumbar spine, the fibula and the phalanx of the hand. Six patients with pain alleviated with salicylates did not have nocturnal pain, but they had all other typical imaging findings. In 20 patients, the imaging findings were not typical. An ellipsoid shape was found in 13 patients, and in four of these patients the largest diameter of the shape exceeded 15 mm (16 [two patients], 20, and 22 mm). Imaging findings that were considered to be atypical in the remaining seven patients were little sclerosis (three patients), intramedullary localization (two patients), and post-surgical or drilling defects that obscured the original lesion (two patients).

The mean age in the group of 60 patients who had either all typical imaging findings, or a histologic diagnosis of osteoid osteoma was 22.6 years (range, 4-53 years). The mean age in the group of 35 patients who were considered not to exhibit all typical imaging findings at the time of treatment and in whom the findings were not confirmed histologically was 23.4 years (range, 4-52 years).

Duration of pain was known in 92 of 95 patients, and mean duration was 2.0 years (range, 0.1-5.5 years). The lesions were located in patients in the following areas: femur, 42 patients; tibia, 14 patients; ischial bone, iliac bone or acetabulum, seven patients, talus, five patients; ulna and humerus, four patients each; lumbar spine and carpal and metacarpal bones of the hand, three patients each; fibula, navicular bone of the foot and cervical spine, two patients each; and cuneiform bone of the foot, dorsal spine, radius and phalanx of the hand, one patient each.

Treatment Success, Failure

Results of treatment were determined by an experienced (26 years of experience) orthopaedic surgeon (A.H.M.T.) with clinical evaluation. After one session of thermocoagulation in 95 patients, treatment was successful in 72 (76%) and unsuccessful in 23 (24%). Treatment was defined as successful when pain had disappeared within two weeks after the procedure and did not recur during clinical follow-up. Treatment was defined as unsuccessful when residual (12 patients) or recurrent (11 patients) symptoms (pain and/or impaired function) that resembled the symptoms at presentation reappeared during follow-up or persisted for more than two weeks after thermocoagulation. In the group with treatment success the mean follow-up was 43 months (range, 5-81 months), and 90% (65 of 72) of patients underwent follow-up for more than 12 months. In the group with treatment failure, the mean follow-up was 36 months (range 10-68 months) and 91% (21 of 23) of patients underwent follow-up of more than 12 months. These clinical results are described elsewhere in detail (11).

Assessment of Risk Factors for Treatment Failure

To identify parameters that were associated with an increased risk of unsuccessful treatment we compared the following parameters in consensus: patient age (G.M.V., A.A.v.d.B.H.), sex (G.M.V., A.a.v.d.B.H) , lesion size (G.M.V., W.R.O.), lesion location and relationship to joint and cortex (G.M.V., W.R.O.), calcification of nidus (G.M.V., W.R.O.), number of needle positions used to coagulate the lesion (G.M.V., W.R.O.), duration of thermocoagulation (W.R.O., A.H.M.T.), needle not placed in the center of the lesion (G.M.V., W.R.O.), percentage of previously treated patients (G.M.V., A.a.v.d.B.H.), and learning curve of the radiologist (G.M.V., A.a.v.d.B.H.). CT scans were retrospectively analyzed in consensus by two experienced musculoskeletal radiologists (G.M.V. and W.R.O., with 10 and 31 years of experience, respectively) to identify problems with visualization of the lesion and/or with targeting of the lesion that contributed to wrong needle positioning. To evaluate the learning curve, or the effect of the number of procedures performed by the radiologist, the procedures were arbitrarily divided into three groups on the basis of the date of treatment. The first 32 patients formed group 1, the next 32 patients formed group 2 and the last 31 patients formed group 3. All procedures were performed by the same radiologist (W.R.O.).

Thermocoagulation

Radiographs and bone scintigraphic images were only used to localize the lesions for CT and were not analyzed in the current study. Helical CT (Tomoscan SR 7000 or AV E 1; Philips, Best, The Netherlands) with a reconstruction slice thickness of 1-2 mm was the imaging method used to assess the previously mentioned imaging parameters. The technique of CT-guided thermocoagulation used is described in detail elsewhere (11;12). Thermocoagulation had been performed by using an electrically isolated hollow needle with a 5 mm unprotected tip that was not cooled (Sluijter-Mehta cannula; Radionics, Burlington, Mass). The protocol used had required heating, to 90^{o} C for 4 minutes for each needle position by using a heating system (Radionics-RFG 3C RF-lesion Generator System; Radionics). The radiologist who performed the procedure (W.R.O.) was allowed to adjust the coagulation time on the basis of individual considerations. Coagulation time was increased when lesion were large (≥ 10 mm), when the needle tip was not placed in the center of the lesion, and most important, when multiple needle positions were used. It was decreased when lesions were small (< 10 mm) or when vulnerable structures, such as skin, cartilage or nerves were close to the lesion. Location and maximum diameter were determined on pre-treatment CT scans by two observers (G.M.V., W.R.O.) in concert who did not have information about success or failure of thermocoagulation. Lesions were arbitrarily classified as either smaller than 10 mm or 10 mm or larger in diameter. Procedural CT scans (obtained during thermocoagulation with the needle positioned for thermocoagulation) and follow-up CT scans obtained in patients with residual or recurrent symptoms (cases of treatment failure) were assessed to determine whether the nidus was properly targeted.

Table 1
Clinical Data and Lesion Size in Relation to Treatment Failure or Success

CLINICAL DATA	Treatment Failure Group (n = 23)		Treatment Success Group (n = 66) [b]	
	< 10 mm Lesion	≥ 10 mm Lesion	< 10mm Lesion	≥ 10mm Lesion
TOTAL NO. OF PATIENTS	12	11	41	25
1 needle position	11	8	27	8
[2-4] needle positions	1	3	14	17
TOTAL NO. OF PATIENTS	12	11	41	25
Coagulation time [a] [2 or 4 min]	9	7	21	5
Coagulation time [> 4 min]	3	4	20	20

[a] Coagulation time was 2 minutes instead of 4 minutes in four patients
[b] Data are numbers of patients. In six of 72 patients, number of needle positions was not recorded, and these patients were excluded from this part of the analysis.

Statistical analysis

Differences in age, sex, and the relationship between the parameters defined previously and presence or absence of treatment failure were evaluated with univariate analysis by using chi-square analysis, the Fisher exact test and unpaired Student *t* test. Interaction between parameters was examined by using chi-square analysis, Fisher exact test and Spearman correlation analysis. Logistic regression analysis was used to determine predictors of treatment failure after one session of thermocoagulation. Parameters that correlated, or had a tendency to correlate, with presence or absence of treatment failure, as well as parameters that displayed interaction with these, were entered in the logistic regression model. The statistical significance of the interaction terms was examined in the logistic regression model, and odds ratios were determined. A backward-stepwise likelihood ratio elimination method was used and a difference with a P-value of less than 0.05 was considered statistically significant. A software package (SPSS 10.0.7; SPSS, Chicago, Ill.) was used for this statistical analysis.

RESULTS

Age and Sex

The mean age of patients in the treatment failure group was 20 years (range, 8-38 years), and in the treatment success group it was 24 years (range, 4-53 years) in the treatment success group. The difference in mean age between the two groups was significant (P = 0.047). There was no difference in age between male and female groups (P = 0.62). There was no significant difference in the male-female ratio, which was 2.3 for the treatment failure group and 3.0 for the treatment success group (P = 0.61).

Lesion Size

The mean maximum diameter of the lesion in the treatment failure group was 10 mm (range, 2-25 mm) and 9 mm (range, 3-22 mm) in the treatment success group. When lesion were stratified according to a diameter smaller than 10 mm, or a diameter of 10 mm or larger, the majority of lesions, both in the treatment failure group (12 out of 23 [52%]), and treatment success group (43 out of 72 [60%]), were smaller than 10 mm in diameter. Diameter (P = 0.75) and percentage of patients with a small lesion (P = 0.52) were not significantly different for the two groups.

Lesion Location

Treatment of 12 of 46 intra-articularly located and 11 of 49 extra-articularly located osteoid osteomas was unsuccessful. This small difference is not significantly different (P = 0.68).

Treatment of 13 of 63 intracortical and 10 of 32 extracortical osteoid osteomas was unsuccessful. This difference was not significant (P = 0.25).

Because of the large variety in types of hosting bone, no meaningful statistical analysis of these data was possible. There were no major differences relative to the overall failure rate of 24 % (23 of 95 patients). Most lesions were located in the femur, and 10 of 42 lesions located in the femur were unsuccessfully treated. The spine was considered to be the most critical location. Two of six patients with lesions in the spine were unsuccessfully treated.

Calcified Nidus

Six of 18 osteoid osteomas without and 17 of 77 of those with a calcified nidus were unsuccessfully treated. This difference was not significant (P = 0.36).

Number of Needle Positions in Relation to Lesion Size

In six (8 %) of 72 patients in the treatment success group the number of needle positions was not recorded. Details about the number of needle positions in relation to lesion size and treatment failure are listed in Table 1. The majority of treatment failures (in 11 of 12 small lesions and eight of 11 large lesions) were seen in the group treated with only one needle position. In the treatment failure group, the number of times only one needle position was used was more frequent than in the treatment success group and the difference was significant (P = 0.01). Multiple needle positions were more frequently used to treat large lesions, and the difference was significant (P = 0.01).

Coagulation Time in Relation to Lesion Size

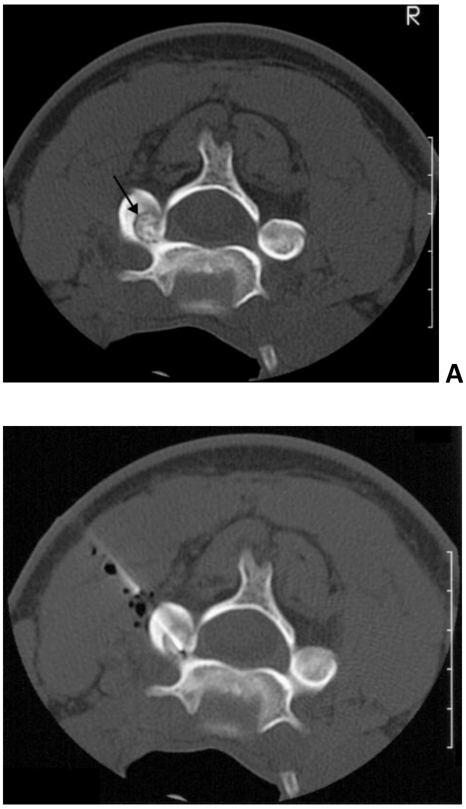
The coagulation time was not properly recorded in six of 72 patients in the treatment success group. Detailed information about coagulation times is listed in Table 1. In four patients, the coagulation time was 2 minutes instead of the required 4 minutes per needle position because of close proximity of a small nidus to cartilage (two patients) or nerves (two patients). The mean coagulation time per procedure was 5 minutes 10 seconds (range, 2-17 minutes) in the treatment failure group and 6 minutes 11 seconds (range, 2-16 minutes) in the treatment success group. Treatment failure occurred more frequently (P = 0.01) in lesions that were coagulated for 2 minutes (three patients) or 4 minutes (13 patients) compared to those that were coagulated for longer than 4 minutes (seven patients). The coagulation time was significantly longer in larger lesions (P = 0.01).

Inaccurate Procedures in Patients with Treatment Failure

In nine (39 %) of 23 patients with treatment failure, problems with positioning of the needle were encountered. In eight of these nine patients, only one needle position was used. In the remaining patient, three needle positions were used. The mean coagulation time used in these nine patients was 5.67 minutes and the mean diameter of the lesion was 9.56 mm. The problems can be subcategorized into two groups for these nine patients: access and visualization problems.

Figure 1
Transverse unenhanced CT image of the right ischium (pelvis) obtained with patient in prone position shows thermocoagulation electrode in place. Lesion (arrow) was difficult to access because of its location deep within the ischial bone. Maximum diameter of lesion was 10 mm, and approach was lateral.

Two lesions in the pelvis were difficult to approach. One of these lesions (maximum diameter, 10 mm) was difficult to reach because of its location deep in the ischial bone (Fig. 1). The other lesion, located in the acetabulum, was difficult to target because of its location close to the joint, and it was, in addition, a large lesion (maximum diameter, 25 mm). Two of nine patients had spine lesions. In these two patients with treatment failure in spine lesions (lumbar spine [diameter, 10 mm] and cervical spine [diameter, 9 mm]), the approach was difficult because of te proximity of nerve roots in these lesions that were located in the pedicles. The vertebral artery and facet joint were also close to the lesion located in the cervical spine (Fig. 2).



A

B

Figure 2
Transverse unenhanced CT images of cervical spine obtained with patient in prone position. Lesion (arrow), located within the left pedicle of C3, was difficult to target because of proximity of nerve roots, vertebral artery and facet joint. Maximum diameter of lesion was 9 mm, and approach was posterolateral. (a) Without thermocoagulation needle in place.
(b) With thermocoagulation needle in place.

The close relationship between the sciatic nerve and an osteoid osteoma (maximum diameter, 7 mm) located in the proximal femur in the fifth patient also complicated the approach. As a consequence the thermocoagulation needle was placed eccentrically within the lesion.

The remaining four of nine patients had osteoid osteomas that were difficult to localize exactly. Sclerosis and post-surgical changes secondary to previous treatment prohibited unequivocal visualization of the nidus in a patient with treatment failure in a lesion (maximum diameter 4 mm) in the femur. Retrospective analysis showed that the tip of the electrode was not placed in the lesion. Similar problems secondary to the presence of sclerosis and cysts were encountered in three patients who did not undergo previous treatment and who had lesions in the capitate bone (maximum diameter, 14 mm), the trapezoid bone (maximum diameter, 2 mm), and the femur (maximum diameter, 5 mm) (Fig.3).

Figure 3
Transverse unenhanced CT image of right hip obtained with patient in supine position. Very small proximal femoral lesion (arrow) was hard to distinguish from surrounding sclerosis. During first thermocoagulation attempt, thermocoagulation electrode was placed immediately adjacent to actual lesion. Maximum diameter was 5 mm, and approach was anterolateral.

Learning Curve

There were no significant differences in number of treatment failures among the three groups (P = 0.66). Nine treatment failures (28 %) occurred in our first group of 32 patients. In the second group of 32 patients there were six (19 %) treatment failures and in the third group (31 patients) there were eight (26 %). The frequency distribution of the demographic, anatomic, and procedure-related parameters tested in this study were not significantly different among the three groups.

Previously Treated Lesions

In three of 10 patients who were treated unsuccessfully in referring hospitals (nine with surgery and one patient with thermocoagulation), treatment failed after thermocoagulation at our institution. This failure rate of 30% is not significantly different (P = 0.70) from the failure rate of 24% (20 of 85 patients) in the group without previous treatment.

Logistic Regression Analysis

As described before, by using univariate analysis we found that age, number of needle positions and time of coagulation correlated with treatment failure. However, interaction was found between number of needle positions and size (P = 0.01), coagulation time and size (P = 0.03) and number of needle positions and coagulation time (P < 0.01). The Spearman correlation coefficient used to describe these interactions were respectively 0.27, 0.23 and 0.76 (P < 0.01 [number of needle positions and lesion size], P = 0.03 [coagulation time and lesion size] and P < 0.001 [number of needle positions and coagulation time], respectively).

Therefore, size of the lesion was also included in the logistic regression model. Backward-stepwise logistic regression analysis was used to identify age and number of needle positions as factors associated with treatment failure (Table 2). Advanced age (mean age, 24 years in the treatment success group *vs* 20 years in the treatment failure group) was associated with a trend of decreasing risk for treatment failure (odds ratio = 0.93; 95% confidence interval 0.88, 0.99). Similarly, if multiple needle positions during thermocoagulation were used, patients were less at risk for treatment failure (odds ratio = 0.10; 95% confidence interval 0.02, 0.41). Patients with a lesion 10 mm or larger seemed more at risk for treatment failure (odds ratio = 2.68); however, the 95 % confidence interval of 0.84 to 8.52 included the 1.00 value. Coagulation time was not an independent predictor of treatment failure. Concordance of the model was good, with observed outcome of 0.77.

Table 2
Predictors of Treatment Failure after One Session of Thermocoagulation with Logistic Regression Model

Variable	β Value	Standard Error	P Value	Odds Ratio	95% Confidence Interval	
					lower	upper
Advanced Age	-0.07	0.03	0.02	0.93	0.88	0.99
[a] Lesion size ≥ 10 mm	0.98	0.59	0.09	2.68 [a]	0.84 [a]	8.52 [a]
Increased no. of needle positions	-2.31	0.73	0.001	0.10	0.02	0.41

[a] Patients with a lesion size ≥ 10 mm or larger seemed more at risk for treatment failure (odds ratio = 2.68); however, the 95 % confidence interval of 0.84 to 8.52 included the 1.00 value
Note: concordance of model was 0.77.

DISCUSSION

Thermocoagulation has been proved to be a safe effective treatment for osteoid osteoma, yet recurrent or residual pain does occur (4;7-10). In our unselected population treatment failure occurred more frequently in young patients who are treated with one needle position only, especially, but not exclusively, when needle placement was inaccurate, or when lesions were large. The use of only one needle position is the most important independent parameter that is associated with an increased risk for treatment failure in lesions of all sizes. The use of one needle position in relatively large lesions was also reported by Lindner et al. (4) as the reason for failed coagulation in two of three patients with recurrent local pain. Location, calcification of the nidus, coagulation time, lesion size, learning curve and previous treatment are not independent risk factors for treatment failure.

In our study, inaccurate needle placement was found to be the cause for treatment failure in nine of 23 patients. Rosenthal et al. (7) mention two patients in whom needle placement was an issue. In one patient, the transverse plane could not be used because of the size of the patient, and in the other patient, close proximity to the neurovascular bundle affected the procedure. We identified two equally important reasons for inaccurate needle placement: (*a*) difficult approach because of close relationship with vital structures such as nerves, or because of deep location, such as in the pelvis, or (*b*) poor visualization of the nidus because of osseous abnormalities that may be secondary to earlier treatment. A solution for the difficult approach is hard to identify, since improvement did not occur in the consecutive procedures performed in 95 patients who were included in this study. The use of dynamic magnetic resonance (MR) imaging to identify poorly visualized lesions prior to the CT-guided thermocoagulation may be a solution based on some reports in the literature and our anecdotal experience (12;13). The use of MR imaging data during the CT-guided procedure may, however, pose a problem. The potential role of dynamic enhanced MR imaging in these situations needs to be addressed in larger patient's cohorts. Alternatively, increasing the coagulated volume can be attractive, as described previously, when no vital structures are close to the lesion.

There is a correlation between treatment success and coagulation time. Coagulation time, however, is not an independent parameter in this study, with a recommended coagulation time of 4 minutes and a minimum of two minutes. The observed difference in coagulation time between the treatment failure and treatment success groups can be explained by the interaction between coagulation time and number of needle positions (Spearman correlation, 0.76). The conclusion that increasing only the coagulation time is not effective in reducing treatment failure is supported by analysis of the coagulation process (12). It appears from our data and data reported in the literature, as well as from a theoretical perspective (14) that an effective coagulation time of 4 minutes per needle position is sufficient and a coagulation time of more than 6 minutes per needle position is probably not necessary (12). Rosenthal et al. (7) described one patient in whom a short coagulation time of 1 minute was thought to have been the reason for failed treatment.

With the technique we used, a spherical zone of approximately 1 cm is coagulated (12). It appears that, even when the needle is positioned in the center of the lesion, this zone is insufficient in a minority of patients. The number of needle tip positions used per procedure, and thus the volume of coagulated tissue, was significantly smaller in the treatment failure group than it was in the treatment success group. The volume of the coagulated tissue can be increased safely, by using multiple needle positions. We used a 5 mm large non-insulated tip. Increasing the size of the non-insulated tip or using a cooled tip to allow greater heat transmission as compared with that with a non-cooled tip will result in a larger treatment zone (12). However, we do not advocate the use of a cooled tip. In regard to the findings of Dupuy et al. (15), we also prefer to coagulate a small volume surrounding the needle tip because of safety considerations. Complications such as vaporization within the tissue, carbonization and unintended injury to normal tissue have been described with use of cooled tips in experimental studies (16).

Young age is a risk factor for treatment failure that is difficult to explain. The practical consequence would be to be more generous in the number of needle positions in young patients.

There were limitations to this study. The size of the population, especially the total number of patients, especially those with treatment failure, is relatively small in relation to various parameters such as lesion location. As a consequence of our approach of allowing multiple needle positions depending on lesion size and location, not all parameters were fixed. We were, however, still able to determine the relationship between these parameters and the treatment failure risk. We did not include histologic confirmation of the diagnosis of osteoid osteoma in all cases, either because the diagnosis based on clinical and imaging findings could be established with confidence in typical cases, or because the pathologist was not able to determine a histological diagnosis because of insufficient biopsy material. Brodie's abscess, especially, can be difficult to differentiate from osteoid osteoma in atypical cases. We believe that strict adherence to the combination of well known clinical and imaging findings reduces this risk to an acceptable level, especially when the limits of histologic diagnosis are taken into consideration.

We conclude that multiple needle positions reduce the risk for treatment failure in lesions of all sizes. Multiple needle positions should especially be used for lesions of 10 mm or larger in diameter or for lesions with a nidus that is difficult to engage to more likely result in treatment success.

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Chapter 5

The healing pattern of osteoid osteomas on computed tomography and magnetic resonance imaging after thermocoagulation

ABSTRACT

Objective. To compare the healing pattern of osteoid osteomas on computed tomography (CT) and magnetic resonance imaging (MRI) after successful and unsuccessful thermocoagulation.

***Materials and Methods*.** Eighty-six patients were examined by CT and 18 patients by dynamic gadolinium-enhanced MRI before and after thermocoagulation for osteoid osteoma. Thermocoagulation was successful in 73% (63/86) and unsuccessful in 27% (23/86) of patients followed by CT. Thermocoagulation was successful in 72% (13/18) of patients followed by MRI. After treatment, the healing of the nidus on CT was evaluated using different healing patterns (complete ossification, minimal nidus rest, decreased size, unchanged size or thermonecrosis). On MRI the presence of reactive changes (joint effusion, "oedema-like" changes of bone marrow and soft tissue edema) and the delay time (between arterial and nidus enhancement) were assessed and compared before and after thermocoagulation.

***Results*.** Complete ossification or a minimal nidus rest was observed on CT in 58% (16/28) of treatment successes (with > 12 months follow-up), but not in treatment failures. "Oedema-like" changes of bone marrow and/or soft tissue oedema were seen on MR in all patients before thermocoagulation, and in all treatment failures. However, residual "oedema-like" changes of bone marrow were also found in 69% (9/13) of treatment successes. An increased delay time was observed in 62% (8/13) of treatment successes and in 1/5 of treatment failures.

Conclusion. Complete, or almost complete, ossification of the treated nidus on CT correlated with successful treatment. Absence of this ossification pattern, however, did not correlate with treatment failure. CT could not be used to identify the activity of the nidus following

treatment. The value of MR parameters to assess residual activity of the nidus was limited in this study.

INTRODUCTION

Thermocoagulation is an effective and safe treatment for osteoid osteoma (1;2). The typical clinical and imaging features of osteoid osteoma on plain radiographs, bone scintigraphy and computed tomography (CT) have been described in detail (3-5). The radiolucent nidus is best seen on thin slice (1 mm to 2 mm) axial CT images, because there is no overlap of surrounding reactive sclerosis and/or periosteal reaction (3-5). More recent papers have focused on the appearance of osteoid osteoma on magnetic resonance imaging (MRI), describing the morphology of the nidus, the surrounding bone, and the adjacent soft tissues as well as the enhancement pattern of the nidus during dynamic MRI imaging (6;7).

The healing pattern of the nidus of osteoid osteomas has been described by Lindner et al. (8) and Martel et al. (9). Since these imaging features have been reviewed in only successfully treated patients, it is unclear whether the imaging features during follow-up correlate with the clinical results of the thermocoagulation. The purpose of this study was, therefore, to compare the healing pattern of osteoid osteomas on CT and MRI in patients after successful and unsuccessful thermocoagulation.

MATERIALS AND METHODS

Patients

The records of 110 consecutive patients diagnosed with osteoid osteoma and treated with thermocoagulation between June 1994 and April 2000 were retrieved from our database. All patients gave informed consent for imaging studies and treatment. Our local institutional review board does not require informed consent for retrospective analysis of clinical data. Thirteen patients were excluded from this analysis because of incomplete follow-up data. Four of these 13 patients were excluded because of incomplete follow-up data and nine of 13 patients were excluded because of a short (fewer than 3 months) but symptom-free follow-up. In the nine patients with fewer than 3 months' follow-up no further follow-up data after 3 months were available. Of these 110 patients, 97 had complete clinical follow-up data. In these 97 patients a total of 121 thermocoagulation procedures were performed. A treatment failure was defined as the presence of residual symptoms persisting at least 2 weeks after thermocoagulation or recurrence of symptoms resembling the initial symptoms (pain and/or impaired function). Otherwise the treatment was considered successful. In 76% (74/97) of these patients treatment was successful and in 24% (23/97) of patients treatment failed after one thermocoagulation session. After the initial thermocoagulation procedure (97 procedures), 22/23 treatment failure patients underwent a second procedure. After this second procedure, two treatment failure patients underwent an additional third thermocoagulation session (one of these patients had recurrence of pain after 44 months) and two other patients had subsequent surgery. Thus, a total of 121 thermocoagulation procedures was performed in our patient group of 97 patients. The clinical outcome, and definitions of diagnosis and outcome have been previously reported (1). Anatomical location is listed in Table 1. Of these 97 patients 51% (49/97) had osteoid osteomas that were located extra-articularly and 49 % (48/97) intra-articularly. As to the location of the nidus within bone 65 % (63/97) were cortical lesions, 23 % (22/97) endosteal lesions, 10% (10/97) were intramedullary lesions and in 2 % (2/97) the location relative to the cortex was not documented.

Table 1
Anatomical location of osteoid osteomas in relation to the treatment outcome (97 patients)

LOCATION	Successful treatment (*n*=74)	Unsuccessful treatment (*n*=23)
Femur	32	10
Tibia	13	1
Pelvis	6	2
Talus	4	1
Humerus	3	1
Ulna	3	1
Carpus	2	2
Metacarpal	2	1
Lumbar spine	2	1
Tarsal	2	1
Fibula	1	1
Cervical spine	1	1
Thoracic spine	1	0
Radius	1	0
Phalanx	1	0

As part of the initial diagnostic work-up of osteoid osteoma prior to thermocoagulation, 50/97 patients underwent MRI, 59/97 patients underwent scintigraphy, 94/97 patients had radiographs performed and all patients underwent CT scanning. After the radiological diagnosis was made using plain radiography, CT, bone-scintigraphy and MRI, CT-guided thermocoagulation was performed under regional or general anaesthesia by a radiologist and/or orthopaedic surgeon. The nidus was localised using incremental CT (Tomoscan CXQ or LX; Philips Medical Systems, Best, The Netherlands) or helical CT (Tomoscan SR 7000 or AV E1; Philips Medical Systems).

Through a small skin incision, the centre of the lesion was engaged, initially by using a Steinmann pin (Synthes, Bettlach, Switzerland) during the first 40 procedures and later by using a 14 gauge “Bonopty” needle system (Radi Medical Systems, Uppsala, Sweden) during the other 81 procedures. A biopsy (including cultures) was performed if the clinical or radiographic appearance of the lesion was atypical, in clinical practice mainly to rule out a Brodie's abscess. If a biopsy was needed, a needle system (Jamshidi; Sherwood Medical, Belfast, Northern Ireland) was introduced over the K wire of the Steinmann pin, or the "Bonopty" needle system drill was removed and exchanged for a 16 gauge biopsy needle. The position of the biopsy needle was always monitored with CT. After the biopsy needle had been removed, a dedicated cannula, and subsequently a radiofrequency probe [Sluijter-Metha Cannula (20 gauge, length 145 mm, active tip 5 mm) for radiofrequency probe and a radiofrequency probe, both by Radionics, Burlington, Massachusetts, USA] were introduced through the penetration cannula.

The temperature at the tip of the thermocoagulation electrode was monitored during the procedure. The lesions were routinely heated to 90°C for 4 minutes (RFG-3C RF-Lesion Generator System, Radionics). After removal of the needle system a CT scan was performed to assess where the nidus was hit and to check for possible complications (e.g. haematoma). CT was able to determine whether the nidus was hit since the needle track was visualized after the procedure.

The mean clinical follow-up time after the only or last thermocoagulation session was 41 months (range, 5-81 months).

CT follow-up

According to our clinical protocol all patients should have had clinical, CT and MRI follow-up at 3 months, 6 months, 12 months and 24 months after thermocoagulation. This succeeded quite well for the clinical follow-up, but was moderately successful for the CT follow-up and not very successful for the MRI follow-up in these patients. The reason was that the orthopaedic surgeon taking care of these patients adhered quite strictly to the clinical portion but not as strictly to the imaging portion of the follow-up protocol.

Eighty-nine percent (86/97) of patients were followed by CT scan after undergoing thermocoagulation. This was after the only thermocoagulation performed in successfully treated patients and after the first or only thermocoagulation procedure performed in treatment failure patients (one of 23 failure patients had only one thermocoagulation session).

The mean CT follow-up time in these 86 patients was 14 months (range, 2-32 months). If patients had more than one follow-up CT scan performed after thermocoagulation, then the last follow-up CT was used to evaluate bone healing. For instance if a patient had a follow-up CT at 6 months and 12 months, this patient was considered to have a CT follow-up of 12 months and this follow-up CT 12 months after thermocoagulation was used to evaluate this bone healing. Thermocoagulation treatment was successful in 63 patients (73 %). In 27% (23/86) of patients thermocoagulation did not result in a significant clinical improvement. The 63 successfully treated patients had a mean CT follow-up of 15 months (range, 6-32 months) after the only thermocoagulation performed, and the 23 treatment failures had a mean CT-follow-up of 10 months (range, 2-28 months) after the first or only thermocoagulation performed (as mentioned before, one of 23 treatment failure patients only had one thermocoagulation procedure). The mean clinical follow-up after the only or last thermocoagulation for this group of 86 patients was 44 months (range, 6-81 months). In all patients the duration of the clinical follow-up was at least as long as the duration of the CT follow-up.

CT follow-up was performed by incremental or helical CT scanning. Incremental CT scanning was performed with a 1-2 mm slice-by-slice thickness (Tomoscan CXQ or LX; Philips Medical Systems). Helical CT scan was performed with a reconstructed slice thickness of 1 mm to 2 mm (Tomoscan SR 7000, or AV E1; Philips Medical Systems).

A nidus was identified in all cases on CT scan before thermocoagulation. We compared follow-up CT scans with the pre-treatment one, and classified changes into one of five groups defined as: 1) complete ossification of the nidus, 2) presence of a minimal nidus rest, 3) decrease in size of the nidus, 4) unchanged size of the nidus, and 5) changed configuration of the nidus, the latter most likely being related to osteonecrosis after thermocoagulation.

MRI follow-up

According to our clinical protocol all patients should have had clinical, CT and MRI follow-up at 3 months, 6 months, 12 months and 24 months after thermocoagulation. As mentioned before, this succeeded quite well for the clinical follow-up, but was not as successful for the CT and MRI follow-up in these patients. In addition, a relative low number of patients were included for MRI follow-up compared with CT follow-up. This is explained by the fact that progressively, during the period between June 1994 and April 2000, only patients with clinical suspicion of treatment failure were selected for further MRI follow-up.

In 18 selected cases a gadolinium-enhanced dynamic MRI was performed during follow-up (mean 12 months, range, 2-28 months) after thermocoagulation. This was after the only thermocoagulation performed in successfully treated patients and after the first or only thermocoagulation procedure performed in treatment failure patients (one of five failure patients only had one thermocoagulation session). As for CT scanning, if patients had more than one follow-up MRI, then the last follow-up MRI was used to assess eventual changes in “oedema-like” alterations of bone marrow and/or soft tissue oedema and joint effusion as well as the delay time. The 13 successfully treated patients in this group had a mean MRI follow-up of 14 months (range, 3-28 months) after the only thermocoagulation and the five treatment failure patients of five months (range, 2-10 months) after the first or only thermocoagulation (as mentioned before, one of five treatment failure patients included had only one thermocoagulation session). The mean clinical follow-up after the only or last thermocoagulation in these 18 patients was 33 months (range, 6-81 months). In all patients the duration of the clinical follow-up was at least as long as the duration of the MRI follow-up.

A non-contrast coronal T1-turbo spin echo (TSE) sequence (TR 550 ms, TE 12 ms), a transverse T1 gradient echo sequence (T1 FFE) (TR 26 ms, TE 8.6 ms) and a transverse T2 TSE sequence with fat suppression (TR 2,980 ms, TE 80 ms) were performed (Gyroscan ACS NT 15, Philips Medical Systems). For dynamic imaging, three consecutive sections were taken through the lesion in the transverse plane. A bolus injection of gadopentate dimeglumine (Gd-DTPA) was administered (0.1 mmol/kilogram body weight, injected at 2 ml/s). A gradient echo sequence was used for the dynamic sequence (T1 FFE, TR 9.5 ms, TE 3 ms) with a temporal resolution of 3 s per image for a total of 120 s. All contrast images were subtracted from the first non-enhanced gradient echo image, and the time of enhancement of the osteoid osteoma was related to the arterial enhancement (delay time). An equilibrium contrast-enhanced series was obtained, consisting of a T1 FFE with fat suppression (TR 45 ms, TE 8.6 ms). All sequences were performed with a 256 pixel x 256 pixel matrix. As for CT scanning, the nidus was demonstrable on all MRI studies before thermocoagulation was carried out.

Two parameters were assessed and compared on the MRI studies performed before and after thermocoagulation: 1) The presence of “oedema-like” changes of bone marrow and/or soft tissue edema or joint effusion; 2) the delay time between the onset of arterial enhancement and enhancement of the nidus, which was assessed by dynamic MRI.

Analysis and statistical correlation

All CT scans and MR images were read and interpreted in consensus by two musculoskeletal radiologists (G.V. and another radiologist). The analyzing radiologists were not aware of the clinical data.

Prior to statistical analysis the five CT categories were grouped in two main categories: (A) advanced bone healing (complete ossification, and minimal residual nidus) and (B) minimal or absent bone healing (decreased size, and unchanged size of the nidus). Further statistical analysis of bone healing on CT was made relative to the treatment outcome (treatment success versus failure), the length of CT follow-up, the location of the nidus within bone (cortical versus an endosteal or an intramedullary location) and the patient's age. Because of the limited number of patients in the group with thermonecrosis, this group was not included in this statistical analysis.

The chi-square and Fisher's exact test were used to evaluate differences in the fraction of patients with advanced bone healing on CT between successfully treated patients and patients with treatment failure. To test the effect of the length of CT follow-up on bone healing we performed the same statistical tests in two subgroups with a CT follow-up of 2-12 months, and > 12 months, respectively. To test for differences in bone healing relative to the location of the nidus within bone (cortical versus an endosteal or an intramedullary location), we used the chi-square test, and to test for differences in age between groups with different healing patterns we used the *t*-test. A P value < 0.05 was considered statistically significant. A software package (SPSS 12.0.1; SPPS, Chicago, Illinois, USA) was used for statistical analysis. The number of patients in the MRI follow-up was too small for an adequate statistical analysis to be performed.

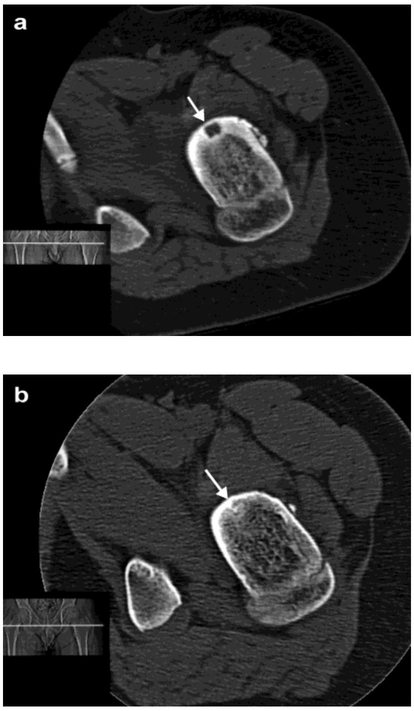

Figure 1
Axial CT image of a nidus in the left hip region (*arrow*) in a successfully treated patient before (a) and 11 months after (b) thermocoagulation. Note complete ossification of the nidus after (successful) thermocoagulation.

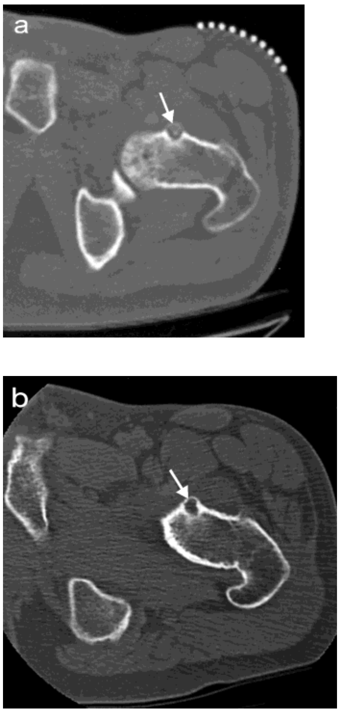

Figure 2
Axial CT image of a nidus in the left hip region (*arrow*) in a treatment-failure patient before (a) and 12 months after (b) thermocoagulation. Note the absence of ossification within the nidus after (unsuccessful) treatment.

RESULTS

Histology

A biopsy was taken in 58% (56/97) of patients. Histology confirmed the presence of an osteoid osteoma in 36% (20/56) of patients. In the remainder a definite histological diagnosis could not be made, because the amount of biopsy material was too small. The diagnosis of osteoid osteoma was confirmed histologically in 22% (19/86) of patients in the CT follow-up group and 22% (4/18) of patients in the MRI follow-up group.

Table 2
Distribution of the CT healing pattern in successfully and unsuccessfully treated patients

CT HEALING PATTERN	Successful treatment (*n*=63)	Unsuccessful treatment (*n*=23)
Complete ossification	15 (24%) [a]	0
Minimal nidus remnant	14 (22%) [a]	0
Decreased diameter	16 (25%)	2 (9%)
Unchanged diameter	15 (24%)	21 (91%)
Thermonecrosis	3 (5%) [a]	0

[a] Complete ossification, a minimal nidus remnant or thermonecrosis was only seen after successful treatment.

CT follow-up

Table 2 shows the distribution of the healing pattern on CT in patients with successful and unsuccessful thermocoagulation**.** Complete ossification, a minimal nidus remnant or thermonecrosis was only seen in patients whose treatment had been successful (Table 2, Figs. 1 and 2). Advanced bone healing was more frequently (P < 0.001) observed in the successfully treated group (29 /63 patients or 46 %) than in the treatment failure group (0 patients). Interestingly, all 15 patients (listed in Table 2) with complete ossification of the nidus had osteoid osteomas that were located within the cortex, and, in patients with an endosteal or an intramedullary location of the nidus, the highest degree of bone healing observed was the presence of a minimal nidus rest, but not complete ossification. This relationship was statistically significant (*P* = 0.03).

Table 3
CT healing pattern in successfully and unsuccessfully treated patients divided in two subgroups according to duration of follow-up with CT scanning

CT HEALING	Successful treatment (*n*=63)		Unsuccessful treatment (*n*=23)	
	2-12 months (*n*=35)	>12 months (*n*=28)	2-12 months (*n*=18)	>12 months (*n*=5)
Complete ossification	7 (20%) [a]	8 (29%) [a]	0	0
Minimal nidus remnant	6 (17%) [a]	8 (29%) [a]	0	0
Decreased diameter	10 (29%)	6 (21%)	2 (11 %)	0
Unchanged diameter	11 (31%)	4 (14%)	16 (89 %)	5 (100%)
Thermonecrosis	1 (3%)	2 (7%)	0	0

[a] No statistically significant (*P* = 0.07) difference in bone healing was identified.

Table 3 illustrates the distribution of the healing pattern for the two subgroups with 2-12 months or > 12 months CT follow-up. Advanced bone healing (the presence of complete ossification and/or a minimal nidus rest) was more frequently seen in the group with > 12 months' follow-up (58% or 16/28 patients) than in the group with shorter follow-up (37% or 13/35 patients), but this difference in bone healing between the two groups was not statistically significant (*P* = 0.07).

No statistically significant relationship between bone healing and age (in successfully and unsuccessfully treated patients) was present both in patients with a shorter (2-12 months) and a longer (> 12 months) CT follow-up period. The *P* value mentioned hereafter was observed in the successfully treated group with a > 12 months CT follow-up (*P* = 0.1).

MRI follow-up

Of the 18 patients who were followed with MRI, treatment was successful in 13 patients (72 %). Because of the limited number of patients included in this MRI follow-up group no adequate statistical analysis could be performed, as has been mentioned previously.

Table 4 shows the distribution of associated reactive bone and soft tissue changes before and after thermocoagulation on MRI in patients with successful and unsuccessful thermocoagulation. All patients had shown "oedema-like" changes of bone marrow and/or soft tissue oedema or joint effusion before thermocoagulation.

Table 4
Bone and/or soft tissue changes on MRI before and after thermocoagulation (TC) in successfully and unsuccessfully treated patients (because of the limited number of patients in the MRI follow-up group, statistical analysis could not be performed)

BONE/SOFT TISSUE CHANGES	Successful treatment (*n*=13)		Unsuccessful treatment (*n*=5)	
	BEFORE TC	AFTER TC	BEFORE TC	AFTER TC
["Oedema-like" changes of bone marrow] + [Soft tissue edema]	5/13	0/13	2/5	2/5
"Oedema-like" changes of bone marrow	8/13	9/13	3/5	3/5
Joint effusion	5/13	5/13 [a]	3/5	3/5
[No "oedema-like" changes of bone marrow] + [No soft tissue edema] + [No joint effusion]	0/13	3/13	0/5	0/5

[a] Of the five successfully treated patients with persistent joint effusion, four also had residual "oedema-like" changes of bone marrow.

After treatment, three successfully treated patients showed complete resolution of these oedematous or "oedema-like" changes (Fig. 3). These three patients had exhibited no joint effusion prior to thermocoagulation and thus no residual changes ("oedema-like" changes of bone marrow, soft tissue oedema or joint effusion) were present after thermocoagulation. A fourth patient in whom these oedematous or "oedema-like" changes had completely resolved had shown persistent joint effusion after successful thermocoagulation. The other nine of 13 treatment successes (69 %) had residual “oedema-like” changes of bone marrow, while all five treatment failures had residual “oedema-like” changes of bone marrow (two of these patients also had residual soft tissue edema).

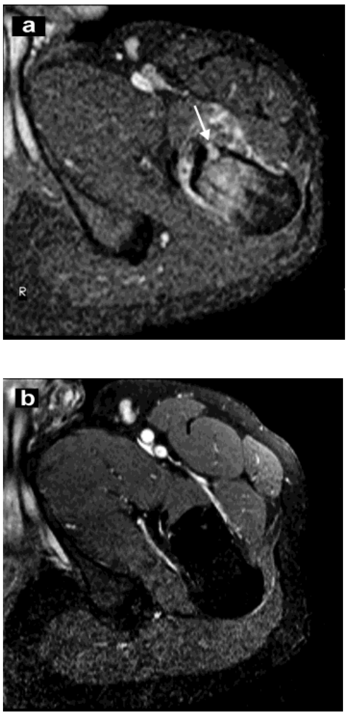

Figure 3
Axial gadolinium-enhanced T1 FFE (TR 45 ms, TE 8.6 ms) with fat suppression of the left hip before (a) and 24 months after (b) successful thermocoagulation. Before thermocoagulation, marked enhancement of the nidus (*arrow*) and the surrounding bone marrow and soft tissues was identified. No residual enhancement in and around the nidus was after (successful) thermocoagulation. The corresponding CT scan (not shown) 24 months after treatment demonstrated a decreased diameter of the nidus, but no complete ossification.

None of the patients with treatment failure showed significant change in the pattern of “oedema-like” changes of bone marrow or soft tissue edema after thermocoagulation (Fig. 4). Complete resolution was thus not observed in this group.

Before thermocoagulation, joint effusion was seen in 44% (8/18) of patients

(Table 4). All lesions in these eight patients had an intra-articular location (three were located in the proximal femur, three in the talus and two in the pelvis). This joint effusion persisted in all patients after thermocoagulation, independent of treatment outcome (five were treatment successes, the other three treatment failures).

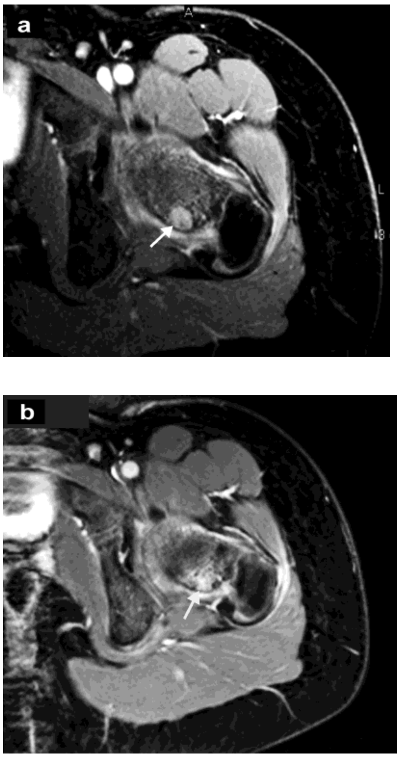

Figure 4
Axial gadolinium-enhanced T1 FFE (TR 45 ms, TE 8.6 ms) with fat suppression of the left hip before (a) and 3 months after (b) unsuccessful thermocoagulation. Before thermocoagulation, marked enhancement of the nidus (*arrow*) and the surrounding bone marrow and soft tissues was identified, persisting at 3 months. On dynamic gadolinium-enhanced MRI (not shown) rapid enhancement of the nidus (with a delay time of 4 s) persisted after (unsuccessful) thermocoagulation.

Table 5 shows the delay time before and after thermocoagulation on dynamic gadolinium-enhanced MRI in patients with successful and unsuccessful thermocoagulation. The results suggest that an increase in delay time tends to be associated with successful treatment, although the number of patients is small. Before thermocoagulation, all osteoid osteomas showed a rapid enhancement within 12 s after arterial enhancement. In the successfully treated patient group eight of the 13 patients (62%) showed either slow (> 12 s delay time) or no enhancement. In the treatment-failure group only one of the five patients showed enhancement after 12 s.

Table 5
Comparison of the MRI delay time (dynamic MRI enhancement) in successfully and unsuccessfully treated patients, before and after thermocoagulation (TC)
(because of the limited number of patients in the MRI follow-up group statistical analysis could not be performed)

MRI DELAY TIME	Successful treatment (*n*=13)		Unsuccessful treatment (*n*=5)	
	BEFORE TC	AFTER TC	BEFORE TC	AFTER TC
0-6 seconds	8	3	4	3
7-12 seconds	5	2	1	1
13-20 seconds	0	2	0	1
>20 seconds	0	1	0	0
No enhancement	0	5	0	0

DISCUSSION

During CT follow-up there was a significant difference in the appearance of the osteoid osteomas between patients with successful and unsuccessful thermocoagulation. Complete, or almost complete ossification of the nidus was only seen in patients who were successfully treated (46% of good respondents). CT findings, however, were of limited value, because absence of this ossification pattern occurred equally in patients with good and poor response to treatment. Ossification occurs mainly within the first year of treatment, as we did not find significant progression of ossification after the first year.

These results are similar to the results published by Lindner et al. (8), who found a complete ossification of the nidus in 53% (8/15) of successfully treated patients. In their study the CT follow-up time was limited to six months and no results of unsuccessfully treated patients were reported. Lindner et al. (8) also reported that osteoid osteomas located within the cortex had a greater tendency to ossify after successful thermo-coagulation than those in other intra-osseous locations. We made a similar observation after successful thermocoagulation: complete ossification of the nidus (present in 15 patients, Table 2) was exclusively seen in patients with a cortical location of the nidus, and this relationship was statistically significant ($P = 0.03$).

A larger fraction of complete ossification of 75% (24/32 patients) was found in a study by Martel et al. (9) in successfully treated patients after 12 months of follow-up with CT scan. The higher percentage of complete ossification in the latter study may be related to the thermocoagulation technique that was applied. In our study a technique was used with a non-cooled tip, and an active tip length of 5 mm, identical to the technique that was used by Lindner et al. (8). From a theoretical perspective (4) we know that this type of electrode creates an approximately 1 cm spherical treatment zone of focal osteonecrosis. Martel et al. (9) used a cooled electrode with an active tip of 10 mm. The treatment zone in this technique is expected to be larger, due to the longer size of the active tip, and the infusion of saline, allowing greater heat transmission (4). This larger treatment zone and thus larger area of thermal injury may have caused more inflammation and secondary ossification, and might, therefore, have contributed to a higher degree of ossification. Because of this larger treatment zone, the use of a cooled tip is generally not advocated for thermocoagulation of osteoid osteomas, because of safety considerations. This applies especially to osteoid osteomas of the spinal canal, because of the risk of thermal injury to the spinal cord or adjacent neurovascular structures (10;11).

Other authors have also commented on the presence of bone healing on CT scan after thermocoagulation previously. Pinto et al. (4) mentioned that partial or complete ossification of the nidus was to be expected over 2-27 months although little or no change in lesion appearance was possible. In some cases the nidus could become indistinguishable from surrounding bone, and reactive changes in adjacent bone and periosteum tended to diminish. Similar observations were made by Ghanem et al. (12) in a series of 12 patients with osteoid osteomas that were successfully treated with thermocoagulation. The lowest percentage of complete ossification observed after successful thermocoagulation of osteoid osteoma was reported by Papagelopoulos et al. (13). They treated 16 intra-articular osteomas of the hip region with a 10 mm active but non-cooled tip. At 12 months' CT follow-up 19 % (3/16) of osteoid osteomas treated in their series demonstrated complete ossification; the other lesions demonstrated partial ossification (six patients) or no change (seven patients).

Martel et al. (9) reported that at a CT follow-up of 12 months all successfully treated patients without obvious bone healing were over 16 years of age. In our study however no statistically significant correlation between bone healing on CT and the patient's age was identified.

The presence of reactive changes in association with osteoid osteoma has been described before (6). Osteoid osteomas produce a large amount of prostaglandins. Elevations of the prostaglandin levels up to 100-1,000 times the normal level have been demonstrated within the nidus of osteoid osteomas (6). The production of such high levels of prostaglandins generates inflammation of the peri-tumoral soft tissue, causing reactive changes (synovitis and/or effusion, and "oedema-like" changes of bone marrow as well as soft tissue edema) (6).

On MRI, all patients showed "oedema-like" changes of bone marrow and/or soft tissue oedema before thermocoagulation or when the treatment had failed (Table 4). However, residual "oedema-like" changes of bone marrow were found in 69% (9/13) of treatment successes. From a theoretical point of view one would expect a total absence of "oedema-like" changes of bone marrow (or soft tissue oedema) after successful thermocoagulation, reflecting the total heat-induced destruction of the hormonally active nidus (6). It is unclear why these “oedema-like” changes of bone marrow persist after successful thermocoagulation. It may be that pain decreases because of the destruction of nerve fibers in and around the nidus (14) after successful thermocoagulation, while hormone production is maintained. Other possible explanations include local mechanical or degenerative changes (6), or reaction to the procedure; in this latter case one would expect these “oedema-like” changes of bone marrow to diminish gradually or disappear after successful thermocoagulation. Further study is required to determine the exact nature and the evolution of these residual “oedema-like” changes of bone marrow present in successfully treated patients.

Joint effusion, present before thermocoagulation, persisted in all of our patients after thermocoagulation, independent of the treatment outcome. Consequently, because this joint effusion persisted in all patients, it was not valuable in differentiating treatment successes from treatment failures in our series. It is likely that the underlying mechanism is the same as for the persistent “oedema-like” changes of bone marrow and soft tissue oedema described above.

The pattern of dynamic enhancement of non-treated osteoid osteomas on MRI has been studied in detail by Liu et al. (7). They assessed the morphology or type of enhancement curve, and found that nine of 11 patients (82%) had peak enhancement of the osteoid osteoma in the early arterial phase with early partial wash-out. In our study we focused on the delay time (time between the onset of arterial and nidus enhancement). Before treatment, all 18 osteoid osteomas showed enhancement within 12 s of the onset of arterial enhancement (Table 5).

Although absence of enhancement was not observed in the group with failed treatment, only 38 % (5/13) of patients with good response showed absence of enhancement (Table 5). Only one patient with poor response had delayed enhancement (> 12 sec.), while 62% (8/13) of successfully treated patients, showed no, or delayed enhancement. Slower enhancement may reflect the replacement of highly vascular tissue by less vascularised or even a-vascular tissue (such as scar tissue, fibrosis or bone) after successful thermocoagulation. Although small numbers do not allow statistical analysis, it seems that the low incidence of change in enhancement indicates low potential for this parameter to be useful in clinical practice.

Although the role of skeletal scintigraphy in the primary diagnosis of osteoid osteoma has been reported in detail previously (15), its use in the detection of residual or recurrent osteoid osteoma after surgery or thermocoagulation has not received much attention. Some case reports (16;17) have indicated, though, that scintigraphy may reliably identify persistent or recurrent osteoid osteoma in a post-operative setting.

CONCLUSION

Minimal or even absent bone healing of the nidus did not necessarily indicate treatment failure, since it was also observed in successfully treated patients. Therefore, based upon CT findings solely, we could not differentiate between treatment successes and failures. The value of MRI in assessing the residual activity of the nidus after thermocoagulation was limited in this study. Clinical evaluation remains essential in identifying patients that may benefit from repeated thermocoagulation.

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Chapter 6

Radiofrequency ablation of spinal osteoid osteoma: clinical outcome

ABSTRACT

Study design: A prospective study on 25 patients with spinal osteoid osteoma treated with radiofrequency ablation (RFA).

Objective: To determine if, and if so, when computed tomography (CT)-guided radiofrequency ablation (RFA) is a safe and effective treatment for spinal osteoid osteomas.

Summary of Background Data: Surgery has been considered the standard treatment for spinal osteoid osteomas. Surgery may cause spinal instability, infection and nervous injury. We evaluated computed tomography (CT)-guided RFA as an alternative treatment.

Methods: A total of 31 RFA procedures in 25 patients with spinal osteoid osteoma were performed, using a 5 mm non-cooled electrode. Clinical symptoms and spinal deformity were evaluated before and after the procedure. Unsuccessful treatment was defined as the presence of residual or recurrent symptoms. The mean follow-up was 70 months (range, 9-142 months).

Results: Nineteen (76 %) patients were successfully treated after one RFA, and all except one after repeat RFA. One patient with nerve root compression needed further surgery. No complications were observed. Spinal deformity persisted in 3/7 patients after successful RFA.

Conclusion: CT-guided RFA is a safe and effective treatment for spinal osteoid osteoma. Surgery should be reserved for lesions causing nerve root compression.

INTRODUCTION

Osteoid osteomas involve the spine in 10-25% of patients, mainly affecting the posterior elements (1). Surgical excision of the nidus has been the standard treatment for spinal osteoid osteomas (2-10). However, spinal osteoid osteomas are difficult to locate during surgery and extensive bone resection may cause spinal instability (2;7;8) and neurovascular injury (3).

Radiofrequency ablation (RFA), as an alternative for surgery, was first described in non-spinal osteoid osteomas by Rosenthal et al. (11) and is used at our institution since 1993 (12). The first successful RFA of a spinal osteoid osteoma was described by Osti et al. (13) in 1998. No clear criteria exist to determine if RFA is technically feasible and safe, but according to Lindner et al. (14) RFA should be reserved for spinal osteoid osteomas ≥ 1 cm away from vital neural structures.

The purpose of this study is to define if and which spinal osteoid osteomas can be effectively and safely treated with computed tomography (CT)-guided RFA.

MATERIALS AND METHODS

Patient inclusion

Between November 1995 and February 2007, 25 consecutive patients with spinal osteoid osteoma were treated with 31 RFA procedures. Twenty patients had one, four patients two and one patient had three RFA sessions.

In all patients prior to RFA, the diagnosis was made in consent by two musculoskeletal radiologists (WRO, GMV) and two orthopaedic surgeons (AHMT, PDSD), based upon the following criteria: localized pain relieved by salicylates or NSAIDs, combined with the presence on CT scan of a < 2 cm sized nidus, with or without central calcification, with or without surrounding sclerosis, and/or periosteal reaction (1;14). None of the patients had previous surgery for their spinal osteoid osteoma. There were no patients rejected for the first RFA session.

Pre-procedural evaluation

The presence of pain, neurological symptoms and spinal deformity were recorded prior to RFA. Spinal deformity was measured according the method of Lippman-Cobb (15) and scoliosis was diagnosed when an angle was ≥ 10° (16).

Prior to RFA the nidus was located by incremental CT (Tomoscan CXQ or LX; Philips Medical Systems, Best, The Netherlands), helical CT (Tomoscan SR 7000 or AV E1; Philips Medical Systems) or multislice CT (Aquilion 4, Toshiba Medical Systems Europe; Zoetermeer, The Netherlands). Two experienced musculoskeletal radiologists (WRO and GMV, with more than 20 and 5 years experience, respectively) evaluated in consensus the CT parameters listed in Table 1.

RFA procedure

The study protocol was approved by the institutional ethical committee and informed consent was obtained in every patient. CT-guided RFA was performed under general anaesthesia by a radiologist (WRO) and/or orthopaedic surgeon (AHMT). With the patient prone, a "Bonopty" needle system [Radi Medical Systems, Uppsala, Sweden; Bonopty Penetration Set-REF 10-1072 (14 gauge), Biopsy Set-REF 10-1073 and Extended Drill-REF 10-1074] was penetrated into the nidus. Through this penetration needle a 15 gauge needle was inserted to take a biopsy. After removal of this biopsy needle a 20 gauge 145-mm-long electrically isolated hollow needle (Sluijter-Metha cannula; Radionics, Burlington, Massachusetts, USA) and a radiofrequency electrode (Radionics) were introduced *via* the penetration cannula. This electrode has a 5 mm-long non-insulated (active) tip, which allows monitoring the electrode-tip temperature during the entire procedure.

The lesion was routinely heated to 90° C for 4 minutes per electrode position by a radiofrequency generator (RFG 3C RF-Lesion Generator System, Radionics). In larger lesions

(> 1 cm) more than one electrode position was used to obtain safe and complete ablation of the entire lesion (17;18). The total coagulation time and the number of electrode positions per procedure were recorded.

Immediately after the procedure CT scanning was performed to check for possible complications (e.g. hematoma), and to confirm that the nidus was hit by visualizing the needle track(s). The mean procedure time, including anaesthesia, was 90 minutes. No prophylactic antibiotic therapy was administered. Patients were routinely discharged the same day and were allowed to take paracetamol for short-term post-operative pain relief.

Post-procedural follow-up and analysis

Immediately before discharge, pain and neurological function were assessed. Clinical follow-up was performed within one week after RFA and at 3, 6, 12, and 24 months after the procedure. Thereafter follow-up data were obtained by postal questionnaire, and if needed with a visit to the outpatient clinic.

The mean clinical follow-up after the final treatment was 70 months (range, 9-142 months) (Table 1). Unsuccessful treatment was defined as the presence of residual clinical symptoms, persisting at least two weeks after RFA, or recurrence of symptoms resembling the initial symptoms. Otherwise the treatment was considered successful.

The occurrence of procedure-related complications was recorded during and after every procedure. Complications were divided according to the time of onset (relative to the procedure) and severity (19). Spinal deformity was reassessed clinically at the time of follow-up and additional spinal overview radiographs were obtained if clinically indicated.

Table 1

Characteristics of 25 patients with spinal osteoid osteoma. Treatment results following CT-guided radiofrequency ablation (RFA)

Level	Location [a]	Dist. [b] (mm)	Primary Treatment Success	Final Successful Treatment [c]	S Pre/Post [d]	F/U [f] (months)
C3	P	< 10	No	RFA	No/No	91
C4	IAP	≥ 10	Yes	--	No/No	129
C6	P	< 10	Yes	--	[26°K+12°S]/ [12°K, no S] [e]	40
T1	P	< 10	No	RFA	No/No	27
T1	PA	< 10	Yes	--	No/No	35
T2	PA	< 10	No	RFA	No/No	9
T4	TP	≥ 10	Yes	--	No/No	63
T4	IAP	≥ 10	Yes	--	No/No	39
T5	P	< 10	Yes	--	No/No	54
T7	P	< 10	No	RFA (2X)	No/No	42
T11	P	< 10	Yes	--	25°/10°	34
T11	B	≥ 10	Yes	--	No/No	27
T12	P	< 10	Yes	--	11°/11°	24
T12	P	≥ 10	Yes	--	15°/No	118
L2	IAP	< 10	Yes	--	No/No	79
L3	TP	≥ 10	Yes	--	25°/No	142
L3	PA	< 10	Yes	--	No/No	135
L3	P	< 10	No	RFA	10°/No	111
L4	P	< 10	Yes	--	No/No	60
L5	IAP	< 10	Yes	--	No/No	100
L5	P	< 10	Yes	--	10°/No	75
S1	LM	< 10	No	Surgery	No/No	58
S3	LM	≥ 10	Yes	--	No/No	133
S3	PA	< 10	Yes	--	No/No	54
S5	LM	≥ 10	Yes	--	No/No	82

[a] Location: IAP = inferior articular process, P = pedicle, PA = posterior arch, TP = transverse process, LM = lateral mass, B = vertebral body
[b] Dist.: the distance between the nidus (nearest margin) and dura or nerve root (mm)
[c] Final successful treatment: RFA = radiofrequency ablation
[d] S = scoliosis, S Pre = scoliosis before RFA, S Post = scoliosis after final successful treatment (radiofrequency ablation or surgery)
[e] K = kyphosis
[f] F/U: follow-up after the final radiofrequency ablation (RFA) session or surgery.

RESULTS

Clinical data

The mean age at the time of the first RFA was 23 years (range, 7-55 years) and the male to female ratio was 2,1. The osteoid osteomas were located mainly in the posterior elements (19/25 lesions, 76%), and were found in descending order of frequency, in the thoracic, lumbar, sacral and cervical spine (Table 1). The mean maximum lesion diameter was 9 mm (range, 5-16 mm). Seventeen lesions (68%) were adjacent (< 10 mm) to vital neurological structures, with one sacral (S1) lesion located < 2 mm from the nerve root (Table 1).

Due to the small lesion size, no tissue could be sampled in 7 patients. Histological confirmation of osteoid osteoma was obtained in 78% (14/18) of the patients in whom biopsy samples were collected. In the other four patients, biopsy material was insufficient to allow a histological diagnosis to be made.

All patients presented with pain, present for a mean of 22 months (range, 9-60 months), which was worse at night, responding to aspirin or NSAIDs. Radicular pain was observed in two patients (one with with a lesion located in S1 (lateral mass), and the other one with a lesion in the posterior arch of T1 (Table 1)).

Seven of 25 patients (28%) had scoliosis (mean 15°, range 10-25°) (Table 1). One patient (with a cervical (C6) lesion) had a kypho-scoliotic deformity (Table 1).

Clinical outcome

Seventy-six percent (19/25) of patients were successfully treated after one RFA session, and all except one (with a sacral (S1) lesion, Table 1) were successfully treated after 1-3 RFA sessions (96% final success rate). After the first RFA, three patients had residual symptoms and three had recurrent symptoms 4 to 40 months later. Four of these patients were symptom free after a second, and one after a third RFA. Surgery, instead of repeat RFA, was performed in the patient with the S1 osteoid osteoma, because this lesion caused persistent nerve root compression (Table 1).

CT scanning performed immediately after the first RFA procedure demonstrated that the needle track(s) had penetrated the nidus in all patients, including the six unsuccessfully treated patients. In all six unsuccessfully and 58% (11/19) of successfully treated patients the lesions were < 10 mm away from vital neural structures (Table 1).

A mean of two electrode positions (range, 1-6 positions) were used during the first session (mean heating time 8 minutes, range, 2-24 minutes). Because of the presumed risk of nervous injury, a reduced coagulation time of two minutes in one position was used initially in the patient with a 7 mm cervical (C3) lesion (Table 1). This patient was successfully treated after repeat RFA with a heating time of four minutes using one electrode position. A 16 mm cervical (C6) lesion was successfully treated after 6 electrode positions with a total heating time of 24 minutes (Fig. 1). Three of seven patients had residual deformity (decreased in two, unchanged in one patient) after successful RFA, but no progression of spinal deformity was observed (Table 1).

Complications of the RFA procedure

Only one patient (with a sacral lesion in the posterior arch of S3, Table 1) required electrode repositioning during the RFA procedure, after demonstrating involuntary muscle contractions. This patient had no post-procedural deficit. No other minor or major complications occurred and all patients could leave the hospital the same day of the RFA procedure and promptly resume their normal activities.

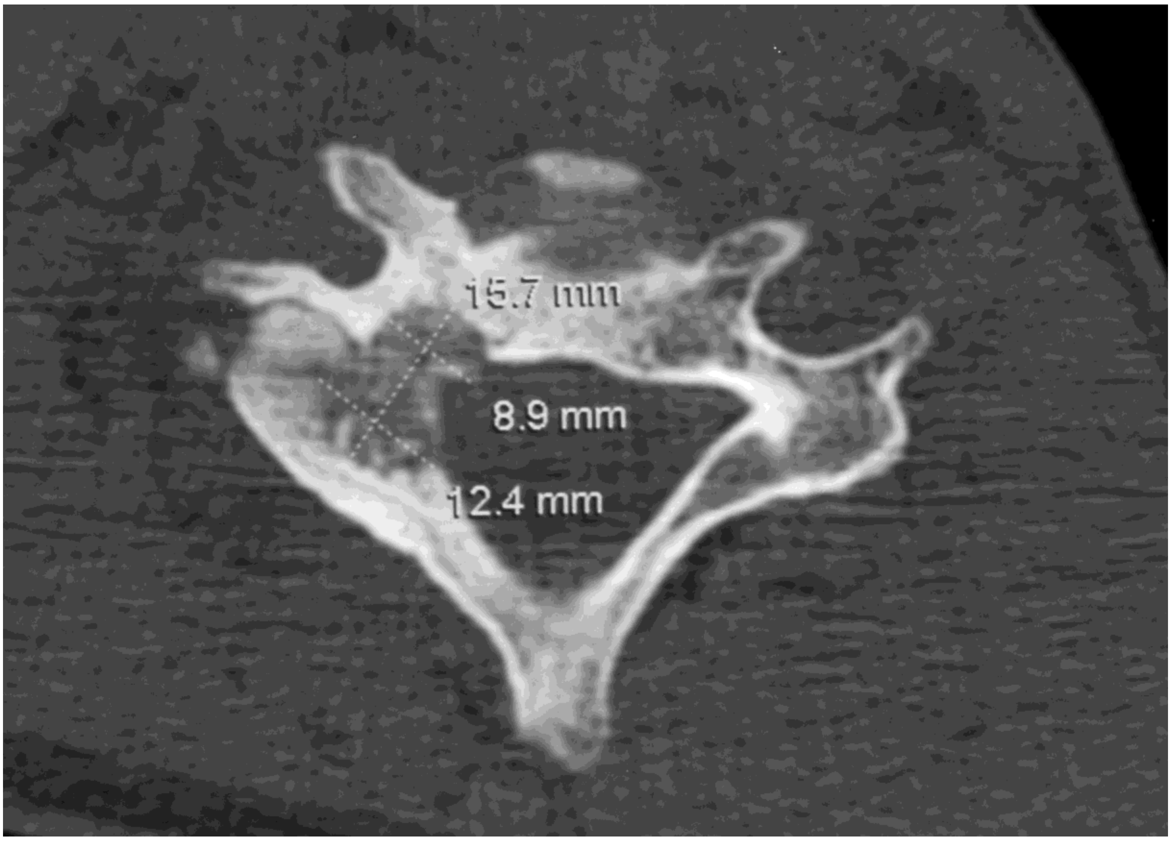

Figure 1
Axial supine CT image of a 16 mm cervical (C6) osteoid osteoma lesion (see callipers) before radiofrequency ablation.

DISCUSSION

RFA is an effective and safe treatment for patients with spinal osteoid osteomas, considering a primary success rate in unselected patients, of 76% (19/25 patients), a final success rate of 96% (24/25 patients), and no post-procedure complications. Only one patient required electrode repositioning during the procedure because of involuntary motion, without any post-procedural deficit. The final success rate of RFA is similar to that of surgery of spinal osteoid osteoma, which has a reported final success rate between 78% and 100% (2-10).

Following RFA, we observed persisting but non-progressive scoliosis in three of seven patients who initially presented with spinal deformity. Following successful surgery, scoliosis is reported to persist in 83% (19/23) of patients, it even progressed in one patient (2;5;7;8).

A major advantage compared to surgery is the minimally invasive nature of RFA. This is illustrated not only by the absence of complications, but also by the absence of morbidity, as all patients could leave the hospital the same day of the procedure without any restrictions in activity. In addition, unlike spinal surgery, RFA can be easily repeated without major bone loss to the spine in case of a local recurrence. Complications after spinal surgery were reported in 17 % (11/66 patients) (2-10), and included infection, neurovascular injury (3), excessive bone removal requiring spinal fusion (2;7;8) and resection of normal bone instead of the nidus (10).

We believe that some technical details are important in keeping spinal RFA a safe procedure. The insulating bone cortex and local heat sinks (the epidural venous plexus and the cerebrospinal fluid circulation) protect the spinal cord and exiting nerve roots against excessive heating (20;21). In our opinion, lesions abutting the dura can be safely treated with RFA, because of the heat sink effects of the spinal fluid and venous plexus. The first successful RFA of an osteoid osteoma abutting the dura was reported in 2000 by Dupuy et al. (21), using a similar 5 mm non-cooled tip. In our patient group 68% (17/25) of patients had lesions < 10 mm away from vital neural structures. Eleven of them were successfully treated after one RFA session, and five other patients were successfully treated after repeat RFA. In only one patient RFA failed, because the lesion in this patient caused nerve root compression, and, in retrospect, this patient should probably not have been considered for RFA. We used in all our RFA procedures a 5 mm non-cooled electrode, which allows precise destruction of the target tissue because it creates a restricted ± 1 cm treatment zone (17;22). Other authors used a cooled tip to treat spinal osteoid osteomas (23-25). Although no complications occurred, a cooled tip is not recommended to treat spinal osteoid osteomas because of the risk of neural injury, not only because the treatment zone increases but also because of its unpredictable size (17;23).

Several minimally invasive alternatives, such as percutaneous resection, intralesional drill excision, gamma- probe guided surgery, and laser ablation have been reported for the treatment of spinal osteoid osteoma (26-30). Of these studies, only laser treatment has results reported in over 10 (twelve) patients, and these results were similar to RFA (26).

Limitations of this study are the small patient numbers and the lack of histological proof in 44% of them. Although numbers are small, this is, as far as we know, the largest study population of unselected patients with spinal osteoid osteoma treated with RFA and a substantial clinical follow-up (mean 70 months).

We conclude that CT-guided RFA of spinal osteoid osteoma with a 5 mm non-cooled electrode tip is an effective treatment for spinal osteoid osteoma, and can be safely performed close to the dura or exiting nerve root. It should be the treatment of choice in lesions ≥ 2 mm away from the nerve root, and surgery should be reserved for lesions adjacent (< 2 mm) to the nerve root causing nerve root compression. In addition, RFA is easily repeatable after unsuccessful treatment.

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Chapter 7

Summary and General conclusion

Samenvatting en Algemene conclusie

Curriculum vitae

SUMMARY

Chapter 1 provides a general introduction to the thesis. The purpose of this thesis is to determine which patients may benefit from radiofrequency ablation (RFA) of their radiologically diagnosed osteoid osteoma. To this purpose patient selection, efficacy relative to clinical, radiological, and procedural parameters, as well as safety of the RFA of both spinal and non-spinal locations of osteoid osteomas were analyzed.

In Chapter 2 the clinical results of RFA in an unselected group of 97 consecutive patients with osteoid osteoma treated with RFA are presented. In this patient group with clinical and radiologic evidence of osteoid osteoma at any location, the clinical symptoms were assessed before and after computed tomography (CT) guided RFA. A good response was defined as disappearance of symptoms attributed to osteoid osteoma that were present at initial presentation. Clinical assessment was performed prior to discharge; within two weeks after the procedure; and at three, six, 12, and 24 months follow-up. After 24 months, a postal questionnaire was used for assessment. The mean clinical follow-up after the only or the last RFA session was 41 months (range, 5-81 months). Response was good after one session of RFA in 74 of 97 patients (76%), (95% CI, 68% to 85%). Patients with persistent symptoms did well after repeated RFA (good response in 10 of 12 patients), but the results of repeated RFA were poor in patients with recurrent symptoms (good response in five of 10). The overall success rate after one or two RFA procedures combined was 92% (89 of 97 patients), (95% CI, 86% to 97%). Complications [hardware failure (one broken biopsy needle tip which had to be removed surgically), skin necrosis] were observed in 2/97 patients (2%).

Percutaneous RFA is a safe and effective method for treatment of osteoid osteoma at any location. Repeated RFA is successful particularly in patients with persistent symptoms.

In **Chapter 3** the theoretical and technical background of the RFA procedure are described. The treatment zone (the amount of tissue ablated) was defined and the criteria necessary for the diagnosis of osteoid osteoma (a typical clinical history and the presence of a distinct radiolucent nidus on thin slice CT scan [1-3mm thickness]) were identified. RFA was performed during general anesthesia, with a routine heating time of four minutes (at 90°C) per electrode position. Contraindications (i.e., cardiac pacemaker) and potential complications (e.g., bleeding, nerve injury, and skin necrosis) are discussed. A detailed description of the RFA procedure and (if applicable) recommendations are provided for the following eight steps involved in the RFA procedure:

1. ***Localization and planning*****:** for a lesion greater than 1 cm more than one electrode positions are recommended. Sometimes entrance through the opposite normal cortex is recommended to avoid neurovascular structures in the proximity of the osteoid osteoma.

2. ***The placement of the grounding pad*** should be close to the planned skin entry to allow the shortest current path through the patient. A large grounding pad reduces the risk of skin burns at the site of the grounding pad.

3. ***A superficial entry with use of tenting*** minimizes the displacement of the needle by overlying tissues.

4. ***The drilling and milling***

5. ***A biopsy*** is recommended in cases with an atypical radiological appearance (e.g., large diameter [diameter > 15 mm], an intramedullary location or post-surgical changes obscuring the original lesion) or atypical clinical criteria (e.g., no nocturnal pain or no typical response to non-steroidal anti-inflammatory drugs). In case of suspicion of Brodie's abscess, histology and cultures should be obtained.

6. *RFA cannula and electrode placement*: generally, the tip of the electrode should be positioned in the centre of the lesion. The penetration cannula should be withdrawn at least 1 cm above the bare tip of the electrode, to prevent contact between the current and the penetration cannula, otherwise tissue burns or loss of current may result. More than one electrode position may be necessary for complete tumour ablation, if tumour tissue extends 5 mm beyond the electrode tip.

7. If after ***the electrode connection*** the tissue resistance exceeds 1000 Ohm (normally 200-600 Ohm), there is an inadequate circuit and the current needs to be excessively increased in order to achieve the desired temperature of 90°C. Possible causes may be an equipment fault or more commonly a “dry tip”, which may be avoided by flushing the RFA cannula with normal saline.

8. *Radiofrequency ablation*: routine heating is performed at 90°C during four minutes per electrode position. The current intensity is one of the most important variables influencing the size of the treatment zone.

Furthermore in this chapter the RFA of osteoid osteomas with specific characteristics are discussed (spinal osteoid osteomas, large osteoid osteomas, osteoid osteomas close to joints, osteoid osteomas adjacent to growth plates and superficial osteoid osteomas). Large osteoid osteomas (> 1 cm diameter) require more than one electrode position, preferably with overlap of treatment zones. Accurate measurement of the lesion size prior to the procedure is therefore critical. In osteoid osteomas close to joints a transarticular approach should be avoided, in order to minimize the risk of infection and to reduce the risk of inadvertent heating of the joint cartilage.

Damage to the growth plate in children should always be avoided during the RFA procedure.

In a superficially located osteoid osteoma the bone-penetration cannula should be withdrawn at least 1 cm above skin level in order to avoid skin burns.

In **Chapter 4** risk factors that may impede a favourable clinical outcome after one RFA for osteoid osteoma were evaluated retrospectively in 95 patients. RFA was successful in 72 (76%) and unsuccessful in 23 patients (24%). To determine these risk factors, certain parameters were compared between these two groups (successfully *vs.* unsuccessfully treated patients) and analysed using X^2 analysis, the Fisher exact test, the unpaired Student t test and/or logistic regression analysis.

The following parameters were analysed: age, gender, size and location of the osteoid osteoma, presence of a calcified nidus, number of electrode positions used for coagulation, coagulation time, accuracy of electrode position, learning curve of the radiologist, and previous treatment. Parameters associated with an increased risk for treatment failure were young age (mean age, 24 years in the treatment success group *vs.* 20 years in the treatment failure group) and a smaller number of electrode positions during RFA. Patients with a lesion of 10 mm or larger tended to have a higher risk for treatment failure. Electrode positioning was inaccurate in nine of 23 patients (39%) with treatment failure, as opposed to none of the 72 successfully treated patients. In eight out of nine patients with treatment failure and inaccurate electrode placement only one electrode position was used. Lesion location, calcification, gender, coagulation time, radiologist's learning curve, and previous treatment were not related with treatment outcome.

We conclude that multiple electrode positions reduce the risk of treatment failure in all patients and should especially be used in large (≥ 10 mm) lesions or lesions that are difficult to engage.

In **Chapter 5** the healing pattern of osteoid osteomas on computed tomography (CT) and magnetic resonance imaging (MRI) after successful and unsuccessful RFA are compared. Eighty-six patients were evaluated by CT and 18 patients by dynamic gadolinium-enhanced MRI before and after RFA for osteoid osteoma. RFA was successful in 63/86 patients (73%) and unsuccessful in 23/86 patients (27%) followed by CT. RFA was successful in 13/18 patients (72%) followed by MRI. After treatment the healing of the nidus on CT was classified using different healing patterns (complete ossification, minimal nidus rest, decreased size, unchanged size or thermonecrosis). On MRI the presence of reactive changes (joint effusion, “oedema-like” changes of bone marrow and soft tissue oedema) and the delay time (between arterial and nidus enhancement) were assessed and compared before and after RFA. Complete ossification or a minimal nidus rest was observed on CT in 16/28 (58%) of treatment successes (with > 12 months follow-up), but not at all in treatment failures, and this difference in bone healing between the two groups (successful *vs.* unsuccessful treatment) was statistically significant ($P < 0.001$).“Oedema-like” changes of bone marrow and/or soft tissue oedema were seen on MRI in all patients before RFA, and in all treatment failures. However, residual “oedema-like” changes of bone marrow were also found in nine of 13 treatment successes (69%). An increased interval between arterial enhancement and enhancement of the nidus on dynamic MRI was observed in eight of 13 treatment successes (62%) and in one out of five treatment failures. However, no statistical analysis could be performed in the MRI follow-up group because of limited patient numbers.

We conclude that complete or almost complete ossification of the treated nidus on CT correlated with successful treatment. Absence of this ossification pattern, however, did not correlate with treatment failure. CT could therefore not be used to identify the activity of the nidus following treatment. The value of MR parameters to assess residual activity of the nidus was limited in this study.

The goal of **Chapter 6** was to demonstrate the efficacy and safety of RFA of spinal osteoid osteomas. Surgery has been considered the standard treatment for spinal osteoid osteomas. Surgery may cause spinal instability, infection and nervous injury. We evaluated computed tomography (CT)-guided RFA as an alternative treatment. Twenty-five patients with spinal osteoid osteoma underwent RFA at our institution. A total of 31 RFA procedures were performed. The presence of pain, neurological signs and spinal deformity were evaluated before and at three, six, 12 and 24 months after the procedure. Beyond two years follow-up data were obtained by postal questionnaire, and if needed with a visit to the outpatient clinic. The mean clinical follow-up after the final RFA was 70 months (range, 9-142 months) and all except one patient had a follow-up of ≥ 24 months. Unsuccessful treatment was defined as the presence of residual symptoms persisting at least two weeks after RFA or recurrence of symptoms. Otherwise the treatment was considered successful. The occurrence of procedure-related complications was recorded after every procedure. Nineteen patients (76%) were successfully treated after one and all except one patient were successfully treated after 1-3 RFA sessions (final success rate of 96%). One patient with nerve root compression needed further surgery. No procedure-related complications were observed. Seven patients (28%) had pre-procedural spinal deformity (Cobb angle of ≥ 10°), which resolved completely, after successful RFA, in four patients. The other three had residual deformity. No progression of spinal deformity was observed after successful treatment.

We conclude that CT-guided RFA is a feasible, safe, and effective treatment for spinal osteoid osteoma and is easily repeatable after unsuccessful treatment. Surgery should be reserved for lesions causing nerve root compression.

GENERAL CONCLUSION

CT-guided RFA is a safe and effective method for the treatment of spinal and non-spinal osteoid osteomas. The primary failure rate after one session of RFA for osteoid osteoma (both spinal and non-spinal) was higher (24%) in our series compared to surgery (approximately 10%) (1-9), but the morbidity after RFA of osteoid osteoma (both spinal and non-spinal) was definitely lower than after surgical resection (1-9). Since loss of bone substance during RFA is minimal, no structural bone weakening (and increased fracture risk) is caused during this procedure. Because of this non destructive minimal invasive nature, with low morbidity, RFA is easily repeatable in case of treatment failure with an ultimate success rate of > 90% (10).

Repeat RFA is particularly successful in patients with persistent symptoms, as opposed to patients who develop new symptoms after a symptom free interval (11).

Furthermore, the risk of treatment failure after RFA for osteoid osteoma may be reduced by using multiple electrode positions especially in large (≥ 10 mm) lesions or lesions that are difficult to engage (12).

One disadvantage of RFA compared to surgery is the limited availability of histological proof. The use of the well known clinical and radiologic criteria to differentiate osteoid osteoma from other lesions, such as an intracortical abscess, is therefore of paramount importance.

Persistence of clinical symptoms remains the most important parameter to diagnose residual disease, as CT and MRI cannot reliably identify residual or recurrent tumour after RFA for osteoid osteoma and have limited value in the follow-up of these patients. The potential role of scintigraphy in the detection of recurrent or residual tumour after RFA of osteoid osteoma was beyond the scope of our study, and has not yet received much attention in the literature (13;14).

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SAMENVATTING

Hoofdstuk 1 is de algemene inleiding op het proefschrift. Het doel van het proefschrift is om vast te stellen welke patiënten met een osteoid osteoom baat hebben bij een percutane behandeling met radiofrequentie ablatie (RFA). In dit proefschrift wordt de effectiviteit van RFA voor de behandeling van osteoid osteomen geanalyseerd, met bijzondere aandacht voor patiëntenselectie, veiligheid en radiologische en proceduregerelateerde parameters.

In **Hoofdstuk 2** worden de klinische resultaten beschreven van RFA in een ongeselecteerde groep van 97 opeenvolgende patiënten met klinische en radiologische kenmerken van een osteoid osteoom. De klinische symptomen voor en na computer tomografie (CT) geleide RFA werden met elkaar vergeleken en een goede therapierespons werd gedefinieerd als het verdwijnen van de bij initiële presentatie aanwezige symptomen, die werden toegeschreven aan het osteoid osteoom. Klinische evaluatie werd uitgevoerd onmiddellijk voor ontslag, binnen twee weken na de procedure, en drie, zes, 12 en 24 maanden na de procedure. Na een periode van 24 maanden werden verdere klinische gegevens verzameld door middel van een per post verstuurde vragenlijst. De gemiddelde klinische follow-up duur na de enige of laatste RFA sessie bedroeg 41 maanden (range, 5-81 maanden). Er was sprake van een goede therapierespons na één enkele RFA sessie bij 74 van de 97 behandelde patiënten (76%), (95% confidentie-interval (CI), 68%-85%). Patiënten met persisterende symptomen reageerden goed op hernieuwde ablatie (goede therapierespons in 10/12 patiënten), maar de resultaten van hernieuwde ablatie waren beduidend minder goed bij patiënten met recidiverende symptomen na een symptoomvrij interval (goede therapierespons in 5/10 patiënten). De globale gecombineerde succesratio na één of twee RFA sessies was 92%

(89/97 patiënten), (95% CI, 86%-97%). Complicaties [afgebroken biopsienaald die chirurgisch verwijderd werd, huidnecrose] werden geobserveerd bij twee van de 97 patiënten (2%).

Percutane RFA is een veilige en effectieve methode voor de behandeling van osteoid osteomen in eender welke locatie. Herhaalde ablatie is vooral succesvol bij patiënten met persisterende symptomen.

In **Hoofdstuk 3** wordt de theoretische en technische achtergrond van de RFA procedure belicht. De definitie van de “treatment zone” (de hoeveelheid weefsel behandeld met ablatie) en de diagnostische criteria voor de diagnose van osteoid osteoom (een typische kliniek in combinatie met een radiolucente nidus zichtbaar op CT scan met dunne coupes [1-3mm dikte]) worden vastgesteld. RFA werd uitgevoerd onder algehele anesthesie, met een routine coagulatie van vier minuten (90°C) per elektrodepositie. Contra-indicaties (cardiale pacemaker) en mogelijke complicaties (zoals bloeding, zenuwbeschadiging, en huidnecrose) worden eveneens besproken. De RFA procedure wordt in detail beschreven, en hierbij ingedeeld in acht verschillende stappen met specifieke aanbevelingen per verschillend procedureonderdeel:

1. ***Lokalisatie en planning*****:** Voor een laesie groter dan 1 cm wordt het gebruik van meer dan één elektrodepositie aanbevolen. Soms is toegang via de overliggende normale beencortex aangewezen om neurovasculaire structuren in de buurt van het osteoid osteoom te vermijden.

2. ***Het plaatsen van een “grounding pad”(aardingslap)*** moet gebeuren dicht tegenaan de geplande naaldtoegang, dit om een zo kort mogelijk stroomtraject te creëren. Een groot “grounding pad” verlaagt de kans op verbranding van de huid gelegen onder dit “grounding pad”.

3. ***Het gebruik van "tenting" bij het inbrengen van de naald door de huid*** minimaliseert de verplaatsing van de naald door het overliggende weefsel.

4. ***"Drilling and milling" (boren en malen)***

5. Een b*iopsie* is aangewezen bij atypische laesies, hetzij met een atypische radiologisch voorkomen (bv. grote osteoid osteomen [diameter > 15 mm], een intramedullair gelokaliseerd osteoid osteoom of de aanwezigheid van postoperatieve veranderingen die de originele laesie maskeren), hetzij met een atypische kliniek (bv. geen nachtelijke pijn of geen typische respons op niet-steroidale anti-inflammatoire geneesmiddelen). Bij verdenking op een Brodie's abces moet materiaal worden afgenomen voor zowel histologische als microbiologische analyse.

6. ***Plaatsen van de RFA canule en elektrode:*** De elektrodetip dient in het algemeen in het centrum van de laesie geplaatst worden. De penetratiecanule moet minimaal 1 cm boven de niet-geïsoleerde tip van de elektrode worden teruggetrokken voor de eigenlijke ablatie. Bij contact tussen het stroomtraject en deze canule kan namelijk weefselverbranding of stroomverlies tijdens ablatie ontstaan. Meer dan één elektrodepositie kan vereist zijn voor het bereiken van complete ablatie van de tumor, zeker als er zich tumorweefsel op meer dan 5 mm afstand van de elektrodetip bevindt.

7. Indien na ***het aansluiten van de elektrode*** de gemeten weerstand meer dan 1000 Ohm (normaal 200-600 Ohm) bedraagt, dan duidt dit op een inadequaat stroomcircuit en moet de stroom buitensporig opgevoerd worden om de vereiste temperatuur van 90°C te bereiken. Een technische panne of, meer frequent, een zogenaamde "dry tip" kan hiervan de oorzaak zijn. Een "dry tip" kan vermeden worden door de RFA canule te spoelen met fysiologische zoutoplossing.

8. Per elektrodepositie wordt gedurende 4 minuten ***radiofrequentie ablatie*** verricht bij een temperatuur van 90°C. De stroomintensiteit is een van de belangrijkste variabelen die de diameter van de “treatment zone” bepaalt.

In dit hoofdstuk worden tevens de technische aspecten beschreven van de RFA behandeling van osteoid osteomen met specifieke kenmerken, zoals spinale osteoid osteomen, grote osteoid osteomen (> 1 cm diameter), para-articulaire osteoid osteomen, osteoid osteomen tegenaan de groeischijf en oppervlakkige osteoid osteomen. Grote osteoid osteomen vereisen meer dan één elektrodepositie, liefst met overlappende ablatie-zones. Een nauwkeurige bepaling van de diameter van de laesie voor de procedure is daarom van primordiaal belang. In para-articulaire osteoid osteomen moet een trans-articulaire toegangsweg worden vermeden om het risico op infectie of thermisch letsel van het gewrichtskraakbeen te minimaliseren. Beschadiging van de groeischijf in kinderen tijdens de procedure moet te allen prijze worden vermeden. In oppervlakkig gelegen osteoid osteomen moet de penetratiecanule tenminste 1 cm boven het huidoppervlak worden teruggetrokken, dit om verbranding van de huid tijdens de ablatie te voorkomen.

In **Hoofdstuk 4** werden de risicofactoren onderzocht die een goede klinische respons op RFA voor osteoid osteoom kunnen verhinderen. Dit werd retrospectief geanalyseerd in een groep van 95 patiënten met één RFA sessie. RFA was succesvol in 72 (76%) en niet succesvol in 23 (24%) patiënten. De volgende parameters werden met behulp van X^2 analyse, de Fisher exact test, de ongepaarde Student t test en/of logistische regressie geanalyseerd: 1) de leeftijd van de patiënt, 2) het geslacht van de patiënt, 3) de diameter en de locatie van het osteoid osteoom, 4) de aanwezigheid van nidus-verkalking, 5) het aantal elektrodeposities gebruikt gedurende de ablatie, 6) de totale coagulatie-duur, 7) de nauwkeurigheid van de positionering van de elektrode, 8) de leercurve van de radioloog (die de procedures uitvoerde), en 9) de invloed van eerdere behandeling.

Parameters geassocieerd met een verhoogd risico op het falen van de RFA behandeling waren een jeugdige leeftijd en een kleiner aantal elektrodeposities tijdens de ablatie. De gemiddelde leeftijd bedroeg 24 jaar in de groep van succesvol behandelde patiënten versus 20 jaar in de groep van niet succesvol behandelde patiënten. Patiënten met een laesie van 10 mm of meer toonden een tendens tot een hoger risico op een niet-succesvolle ablatie. De positionering van de elektrode tijdens ablatie was accuraat in alle 72 succesvol behandelde patiënten, maar was inaccuraat in negen van de 23 (39%) niet-succesvol behandelde patiënten. In acht van deze negen patiënten werd slechts één elektrodepositie gebruikt. De locatie van de laesie, aanwezige nidus-verkalking, het geslacht van de patiënt, de coagulatie-duur, de leercurve, en eerdere behandeling van het osteoid osteoom hadden geen significante weerslag op het al dan niet slagen van de RFA.

Het gebruik van multiple elektrodeposities vermindert het risico op niet-succesvolle behandeling bij alle osteoid osteomen en multipele elektrodeposities zijn voornamelijk aangewezen zijn bij grote (≥ 10 mm) of moeilijk toegankelijke osteoid osteomen.

In **Hoofdstuk 5** wordt het genezingspatroon van osteoid osteomen na succesvolle en niet-succesvolle RFA met elkaar vergeleken. Dit genezingspatroon werd beoordeeld met computer tomografie (CT) en magnetische resonantie imaging (MRI).

Zesentachtig patiënten werden onderzocht met CT voor en na RFA behandeling van het osteoid osteoom. RFA was klinisch succesvol in 63 (73%) en niet succesvol in 23 (27%) van de 86 patiënten. Na de behandeling werd de genezing van de nidus op CT ingedeeld op basis van de volgende patronen: volledige ossificatie, discrete nidus-rest, afgenomen nidus-diameter, ongewijzigde nidus-diameter of thermonecrose. Gevorderde botheling (de aanwezigheid van volledige ossificatie van de nidus of een discrete nidus-rest) was op CT aanwezig in 16 van de 28 succesvol behandelde patiënten (58%) met een CT follow-up > 12 maanden, maar werd niet gezien na niet-succesvolle ablatie. Dit verschil in botheling was statistisch significant ($P < 0.001$).

Achttien patiënten werden onderzocht met dynamische MRI voor en na RFA behandeling van het osteoid osteoom. RFA was succesvol in 13 van de 18 patiënten (72%). Op MRI werden de aanwezigheid van reactieve veranderingen (gewrichtsvocht, beenmergoedeem en wekedelen-oedeem) en de "delay time" (de latentietijd tussen arteriële aankleuring en aankleuring van de nidus) beoordeeld en vergeleken voor en na ablatie. Beenmergoedeem en/of wekedelen-oedeem waren zichtbaar op MRI in alle patiënten voorafgaand aan de ablatie, en ook in alle niet succesvol behandelde patiënten. Echter ook in negen van de 13 succesvol behandelde patiënten (69%) was beenmergoedeem aanwezig. Een toegenomen interval op MRI tussen arteriële aankleuring en aankleuring van de nidus werd aangetroffen in acht van de 13 succesvol behandelde patiënten (63%) en in één van de vijf niet-succesvol behandelde patiënten. In de patiënten opgevolgd met MRI kon echter geen adequate statistische analyse uitgevoerd worden wegens een te klein aantal patiënten in deze groep.

Gevorderde botheling van de nidus op CT na RFA correleert met een goede klinische therapierespons. Omdat de afwezigheid van gevorderde botheling niet correleert met een niet-succesvolle behandeling, is CT echter niet geschikt om de activiteit van de nidus te evalueren na RFA. De rol van MRI bij het opsporen van resterende nidus-activiteit na RFA van een osteoid osteoom was beperkt in deze studie.

In **Hoofdstuk 6** was het doel de effectiviteit en de veiligheid van RFA van spinale osteoid osteomen te demonstreren. Chirurgie is steeds beschouwd als de meest geschikte behandeling voor spinale osteoid osteomen. Chirurgie kan echter spinale instabiliteit, infectie en zenuwbeschadiging veroorzaken. Wij evalueerden computer tomografie (CT)-geleide RFA als een alternatieve behandelingsmethode. 25 patiënten met een spinaal osteoid osteoom ondergingen RFA in ons ziekenhuis. Hierbij werden in totaal 31 procedures uitgevoerd. De aanwezigheid van pijn, neurologische symptomen en spinale deformiteit (scoliose en/ of kyphose) werden geëvalueerd voor de procedure en drie, zes, 12 en 24 maanden na de procedure. Twee jaar na RFA werden aanvullende klinische gegevens verzameld door middel van een per post verstuurde vragenlijst, en zo nodig werd de patiënt opgeroepen voor verder klinisch onderzoek. De gemiddelde klinische follow-up na de finale RFA was 70 maanden (range, 9-142 maand) en alle patiënten behalve één hadden een follow-up van ≥ 24 maanden. Niet-succesvolle behandeling werd gedefinieerd als de aanwezigheid van persisterende symptomen (twee weken na de RFA procedure), of recidiverende symptomen na een initieel symptoomvrij interval. In alle andere gevallen werd de behandeling als succesvol beschouwd. Het optreden van eventuele complicaties werd genoteerd na elke procedure. Negentien van de 25 patiënten (76%) werden met succes behandeld na één RFA sessie, en alle patiënten behalve één werden met succes behandeld na 1-3 RFA sessies (succesratio van 96%). Bij één patiënt was verdere chirurgische behandeling noodzakelijk, omdat het osteoid osteoom de aanliggende zenuwwortel comprimeerde. Geen enkele complicatie werd geobserveerd na de in totaal 31 uitgevoerde procedures. Zeven patiënten (28%) patiënten hadden geassocieerde spinale deformiteit (hoek van Cobb ≥ 10°) voor de procedure. Deze deformiteit verdween volledig in vier van deze patiënten na succesvolle ablatie; de overige drie toonden residuele deformiteit. Er werd geen toename van spinale deformiteit gezien na succesvolle RFA.

CT-geleide RFA is een een veilige en doeltreffende behandelwijze is voor een spinaal gelokaliseerd osteoid osteoom; bovendien is deze behandeling eenvoudig te herhalen na eerdere onsuccesvolle ablatie. Chirurgie moet specifiek worden voorbehouden voor spinale osteoid osteomen die wortelcompressie veroorzaken.

ALGEMENE CONCLUSIE

CT-geleide RFA is een veilige en effectieve methode voor de behandeling van zowel spinale als niet-spinale osteoid osteomen. Het percentage onsuccesvolle behandelingen na één ablatie-sessie voor osteoid osteoom was hoger (24%) in onze studie vergeleken met de chirurgische resultaten uit de literatuur (ongeveer 10%) (1-9). De morbiditeit na RFA voor osteoid osteoom (spinaal en niet-spinaal) was echte beduidend lager dan na operatieve resectie (1-9). Omdat het verlies van botsubstantie minimaal is tijdens RFA, veroorzaakt deze procedure geen verhoogd risico op fractuur. Bovendien kan RFA vanwege het minimale invasieve karakter en zijn lage morbiditeit, zonder probleem herhaald worden na een eerder mislukte behandelsessie (10).

Een herhaling van de RFA procedure heeft een hoge kans op klinisch succes bij patiënten met persisterende symptomen in tegenstelling tot patiënten met recidiverende symptomen na een initieel symptoomvrij interval (11).

Het gebruik van multipele elektrodeposities kan het risico op een niet-succesvolle RFA behandeling reduceren in het bijzonder bij grote (≥ 10 mm) of moeilijk toegankelijke osteoid osteomen (12).

Een nadeel van RFA is het lagere percentage van histologische bevestiging na de behandeling ten opzichte van chirurgie. Daarom is in de dagelijkse praktijk het gebruik van de diagnostische (klinische èn radiologische) criteria voor de diagnosestelling van osteoid osteoom van het opperste belang, omdat deze criteria toelaten om een osteoid osteoom te onderscheiden van andere aandoeningen zoals een intracorticaal abces zonder histologische bevestiging.

Omdat CT en MRI niet met zekerheid de aan- of afwezigheid van tumorrest of recidief na RFA voor osteoid osteoom kunnen vaststellen, hebben beide beeldvormende technieken slechts een beperkte rol bij de follow-up na RFA, en blijft de kliniek, met de aanwezigheid van persisterende of hernieuwde klachten, de belangrijkste parameter bij de diagnosestelling van aanwezig actief tumorweefsel na behandeling. De potentiële rol van skeletscintigrafie in de detectie van tumorrest of recidief na RFA voor osteoid osteoom maakte geen onderwerp uit van deze studie, en is tot op heden niet uitgebreid behandeld in de wetenschappelijke literatuur (13;14).

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