Jpn J Radiol (2011) 29:138–143
DOI 10.1007/s11604-010-0529-7

ORIGINAL ARTICLE

Percutaneous radiofrequency ablation of osteoid osteoma using cool-tip electrodes without the cooling system

Masaya Miyazaki · Jun Aoki · Akiko Miyazaki
Takahito Nakajima · Yoshinori Koyama
Tetsuya Shinozaki · Keigo Endo

Received: August 16, 2010 / Accepted: October 6, 2010

Abstract
Purpose. The aim of this study was to evaluate the efficacy of percutaneous radiofrequency ablation (RFA) for osteoid osteoma (OO) using cool-tip electrodes without the cooling system.
Materials and methods. A total of 17 patients (13 males, 4 females; mean age 19.1 years; range 7–49 years) with OO (tibia, $n = 7$; femur, $n = 5$; acetabulum, $n = 2$; radius, $n = 1$; talus, $n = 1$; lumbar spine, $n = 1$) underwent RFA. Using a cool-tip electrode without the cooling system, the lesion was heated to 90°C for 4 or 5 min. Procedures were considered technically successful if the electrode was placed into the nidus and the target temperature was reached and maintained for at least 4 min. Clinical success of the treatment was defined as complete or partial pain relief after RFA.
Results. All procedures were considered technically successful, although two patients encountered complications (pes equinus contracture, skin burn). Altogether, 16 of the 17 patients (94.1%) achieved complete or partial pain relief after primary RFA. Two patients had pain recurrence, with one of them treated successfully with a second RFA. The overall clinical success rate was 88.2%. Histological findings confirmed the presence of OO in 13 patients (76.5%).
Conclusion. Percutaneous RFA of OO using cool-tip electrodes without the cooling system is a safe, effective procedure.

Key words Osteoid osteoma · Radiofrequency ablation · Cool-tip electrode · CT fluoroscopic guidance

M. Miyazaki (✉) · A. Miyazaki · T. Nakajima · Y. Koyama · K. Endo
Department of Diagnostic and Interventional Radiology, Gunma University Graduate School of Medicine, 3-39-15 Showa-machi, Maebashi 371-8511, Japan
Tel. +81-27-220-8612; Fax +81-27-220-8409
e-mail: mmiyazak@gunma-u.ac.jp

J. Aoki
Department of Radiology, Gunma General Hospital, Maebashi, Japan

T. Shinozaki
Department of Orthopedic Surgery, Gunma University Graduate School of Medicine, Maebashi, Japan

Introduction

Osteoid osteoma (OO), first described in 1935 by Jaffe, is a relatively common benign bone tumor, most often found in children and young adults; and it is more common in males. OO is characterized by a nidus surrounded by sclerotic bone that usually measures <15 mm. Radiographic imaging shows a radiolucent, sometimes centrally mineralized nidus surrounded by sclerosis and periosteal bone reaction. The clinical hallmark of the lesion is local pain, typically more severe at night, which subsides promptly after administration of salicylates or nonsteroidal antiinflammatory drugs (NSAIDs). Other possible symptoms include growth disturbances, bone deformity, painful scoliosis, and, if located in a joint capsule, joint swelling, synovitis, restricted joint motion, and contracture.[1–4]

Pain can subside after several years of conservative treatment with analgesics. However, the traditional common curative treatment has been surgical excision, not only of the nidus but also of the surrounding normal

bone, which may result in complications such as hematoma, infection, and fracture. Therefore, surgical excision requires a long period of hospitalization, during which time the patient cannot bear weight on the affected limb, resulting in a delay in resumption of physical activity. In addition, preoperative localization as well as identification of the nidus position during surgery are difficult, causing relapses.

Percutaneous RFA of OO (OO-RFA) is a promising interventional radiology technique that was first described by Rosenthal et al. in 1992.[5] Compared with surgical excision, this procedure can easily destroy the nidus of OO without removing the surrounding normal bone. Since the introduction of this technique, several groups have successfully adopted it and have described its outcomes and side effects.[6–10]

Several studies have reported that OO-RFA is a highly effective, minimally invasive, safe procedure. However, to the best of our knowledge, almost all studies used a 5- to 10-mm straight electrode without a cooling system or a 10-mm cool-tip electrode with a cooling system.[6–10] In the present study, we evaluated the efficacy of OO-RFA using 10-mm cool-tip electrodes without a cooling system.

Materials and methods

Patients

From 2002 to 2008, a total of 18 patients with a clinical diagnosis of OO were treated with percutaneous RFA at our institution. All patients had a clinical picture characteristic of OO (pain at night or at rest that disappears or improves after administration of salicylates or NSAIDs). They also had typical findings on radiographs and computed tomography (CT) and/or magnetic resonance imaging (MRI) with clear depiction of a nidus. One patient who had a nidus in the transverse process of the cervical spine (C6) was excluded from this study because the patient was treated by RFA using a different type of RF system (Neuro Therm JK3; Toyo Medic, Tokyo, Japan) to prevent ablation of the spinal cord.

A total of 17 patients (13 males, 4 females; mean age 19.1 years, range 7–49 years) with 18 OO lesions (one patient had two nidi in a single bone) underwent RFA using the cool-tip RF ablation system (Century Medical, Tokyo, Japan) without the cooling system. The lesions were located in the tibia ($n = 7$), femur and femoral head/neck ($n = 5$), acetabulum ($n = 2$), radius ($n = 1$), talus ($n = 1$), and lumbar spine ($n = 1$) (Table 1).

The patients or their legal guardians were informed about this treatment; and alternative treatments, open surgery, and percutaneous excision were presented. Informed consent was obtained in all cases.

Procedures

The interventional procedures of OO-RFA in this study were conducted as follows and are shown in Fig. 1. After appropriate anesthesia (10 general, 6 spinal, 1 spinal/epidural anesthesia), the patients were placed on the computed tomography (CT) table used for the intermittent CT fluoroscopic guidance. Continuous blood

Table 1. Summary of patient information and treatment course

Case no.	Sex	Age (years)	Location	Maximum diameter of nidus (mm)	Pathology confirmation	Pain relief	Pain recurrence
1	M	9	Tibia	5	Yes	Complete	No
2	M	12	Tibia	3	Yes	Complete	No
3	F	24	Femur	6	Yes	Complete	No
4	M	49	Femur	9	Yes	Complete	No
5	M	30	Pedicle L4	8	Yes	Complete	No
6	M	14	Acetabulum	15	Yes	Complete	Yes
7	F	15	Tibia	15	No	Complete	No
8	M	29	Femoral neck	10	No	Complete	No
9	M	10	Femoral head	6	Yes	Complete	No
10	M	7	Talus	6	Yes	Complete	No
11	M	30	Tibia	23	No	Partial	Yes
12	M	23	Femur	5	Yes	Complete	No
13	M	16	Radius	6	Yes	Complete	No
14	F	14	Tibia	13	Yes	Complete	No
15	M	9	Tibia	13	Yes	Complete	No
16	M	17	Tibia	5 and 8[a]	Yes	Complete	No
17	F	17	Acetabulum	12	No	None	NA

NA, not applicable

[a] Two nidi in the same bone

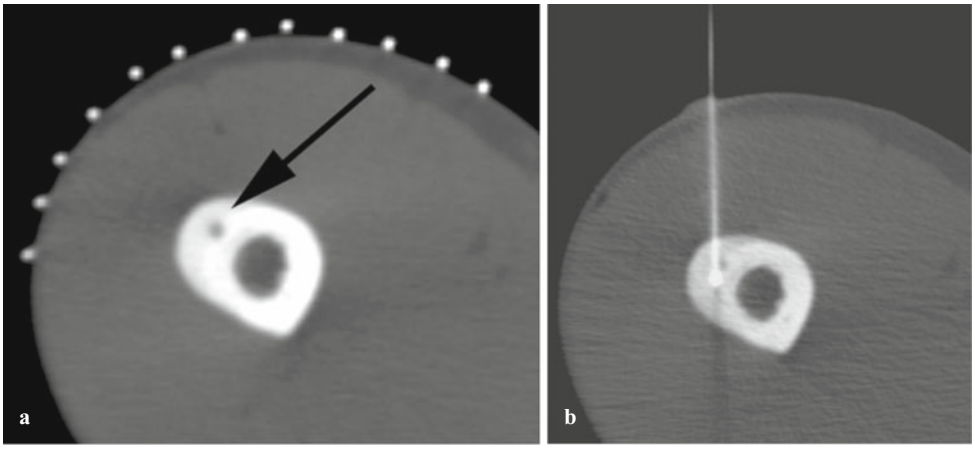

Fig. 1. **a** Osteoid osteoma located at the right femoral shaft. Computed tomography (CT) image shows the nidus located at the periosteal portion (*arrow*) surrounded by the bone reaction. **b** Radiofrequency ablation (RFA) was performed on the lesion using a 10-mm cool-tip electrode without the cooling system

pressure monitoring and pulse oximetry were performed. Two grounding pads were fixed to the appropriate position of the patient and connected to a radiofrequency (RF) generator (Cool-tip RF generator CC-1; Century Medical, Inc., Tokyo, Japan) to close the electric circuit. After skin preparation, using the intermittent CT fluoroscopic guidance, an 11.0- or 14.5-gauge bone biopsy needle (Ostycut, Medicon, Osaka, Japan; or Jamshidi, Care Fusion Japan, Tokyo, Japan) was introduced into the tumor. If the surrounding bone was too hard to penetrate using a biopsy needle, osseous access was established using a bone-penetrating needle (Kirschner wire; Mizuho Ikakougyo, Tokyo, Japan). A biopsy specimen was removed for histological examination, and a 17-gauge, straight, rigid RF electrode with a 10-mm exposed tip (Cool-tip; Century Medical, Inc.) was introduced into the tumor. After connecting the RF electrode to the RF generator, RFA was performed in the manual control mode without the cooling system. The temperature at the tip of the electrode was monitored during the procedure. The lesion was routinely heated to 90°C for 4 or 5 min using the RF generator. If the lesion was large or elongated, several adjacent-level treatments were performed to ensure complete ablation of the tumor.

Procedures were considered technically successful if the electrode was placed in the tumor and the target temperature (90°C) was reached and maintained for at least 4 min. Follow-up was scheduled in the form of clinical visits to one of the collaborating orthopedic surgeons at 1–2 weeks (short-term follow-up) and every 1–6 months (long-term follow-up—if possible) after treatment. The orthopedic surgeons conducted the efficacy assessment by means of oral interviews after the treatment. When the pain was completely gone after the procedure, the treatment was judged to have provided complete pain relief. When the pain was partially decreased but not completely gone, the treatment was judged to have provided partial pain relief. When despite treatment the pain increased, the treatment was judged to be ineffective. The efficacy of the therapy (clinical success rate) was assessed according to the proportion of cases in which complete and partial pain relief was achieved. Regardless of any changes in the pain, the treatment was also judged to be ineffective if the need for analgesics increased over what was required before treatment. Patients or their guardians were asked to contact the orthopedic surgeon immediately if symptoms recurred after the last clinical visit.

Results

All procedures were completed and considered technically successful, although two patients encountered a postoperative complication (a pes equinus contracture induced by penetration of the calf muscles in one and a skin burn due to the soft tissue being very thin over the lesion). These patients recovered fully after several weeks with no further treatment.

In all, 15 of the 17 patients achieved complete pain relief, and 1 patient achieved partial pain relief at the time of the short-term follow-up. Therefore, the primary clinical success rate was 94.1% (16/17). One patient achieved no pain relief despite two treatment sessions. Recurrence of local pain was seen in two patients 2 and 3 months after treatment, respectively. These patients initially had relatively large nidi, with maximum diameters of 15 and 23 mm, respectively (mean diameter of nidi in our study was 9.3 mm). One recurrence was treated successfully and achieved complete pain relief with a second RFA (Fig. 2), and the other was treated with surgical resection. Therefore, the overall clinical success rate of this procedure was 88.2% (15/17).

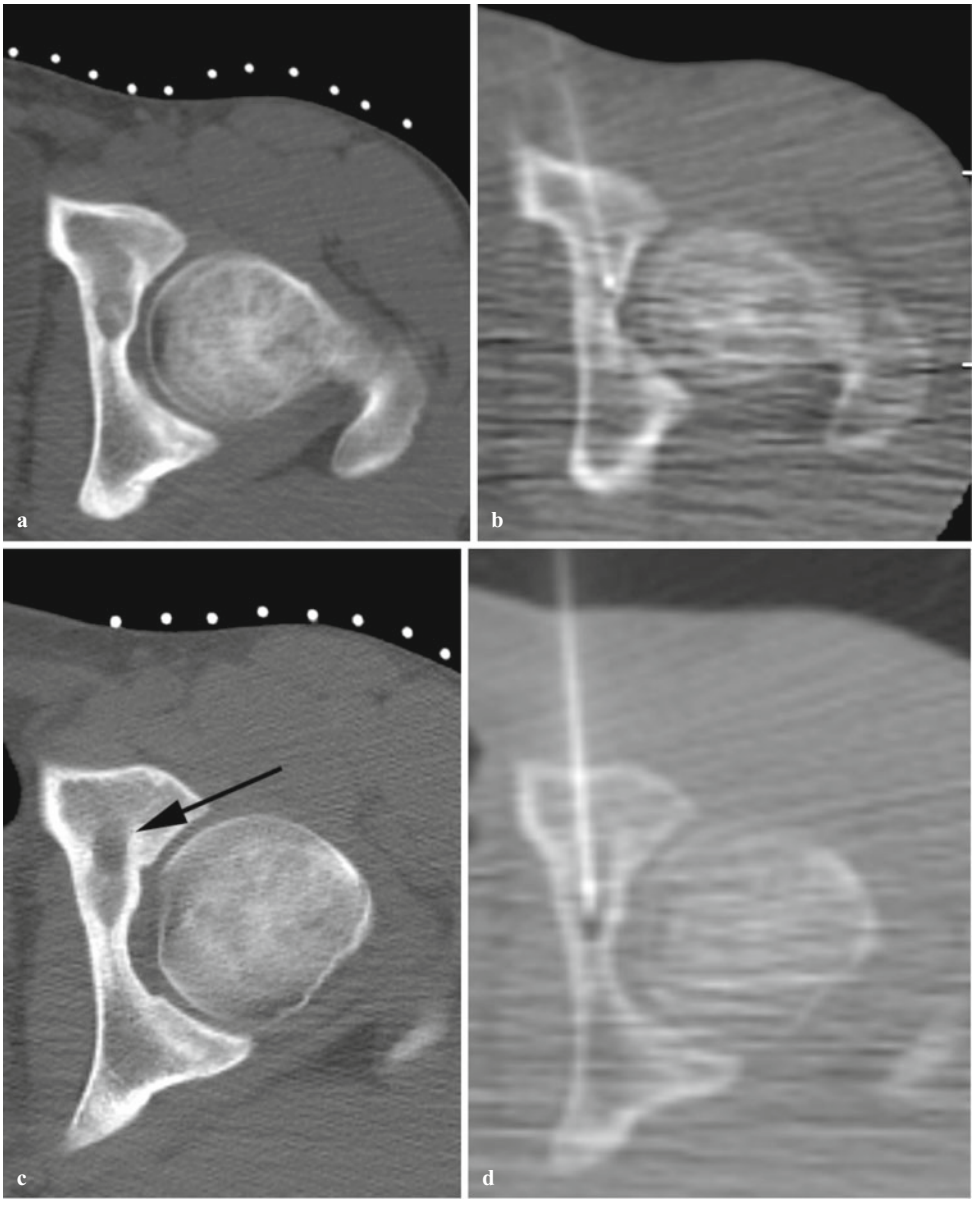

Fig. 2. Case 6: a 14-year-old boy with osteoid osteoma at the left acetabulum. **a** CT image shows the nidus located at the bone marrow with small central mineralization. **b** RFA was performed for the lesion using a 10-mm cool-tip electrode without the cooling system. **c** Three months after the procedure, symptoms recurred, and the CT image reveals the recurrent lesion (*arrow*) at the anterior part of the prior ablated area. **d** A second RFA was performed for the recurrent lesion, and the pain subsequently resolved

Biopsy specimens for histological diagnosis were obtained in all cases. Histological findings confirmed the presence of OO in 13 (76.5%) of 17 patients.

The mean follow-up time for this study was 12.4 months (range 1–40 months).

Discussion

The traditional treatment for painful OO has been conservative treatment with analgesics (salicylates or NSAIDs) or surgical excision. Percutaneous RFA of OO was first reported by Rosenthal et al. in 1992,[5] and many articles have been subsequently reported describing the procedure,[6–10] which is being increasingly accepted worldwide. The efficacy rates of RFA for OO have been reported as 76%–100% by several authors, and the complication rate has also been reported as 1%.[6,7,9–17] A study comparing the results of surgery and with those of percutaneous RFA showed that the recurrence rate for the two treatments was similar, but the hospital stay was longer with surgery than with RFA.[18] Our results, with 94.1% primary success and 88.2% overall success and with two minor complications, are compatible with those of previous reports.

The noncooled electrode with a 5-mm exposed tip has been commonly used for the OO-RFA procedure. In the present study, cool-tip electrodes with a 10-mm exposed

tip were used because the 5-mm electrodes were not available in our country. However, we believe that the 10-mm electrodes were suitable for our patients because the mean maximum size of the nidi was 9.3 mm.

Vanderschueren et al. postulated in their study that the reason for initial failures with this treatment was that the bone volume that could destroyed was inadequate and that several passes would be required for the treatment to be successful.[19] Therefore, our procedure using 10-mm electrodes can be considered to have a marked advantage because the electrodes can ablate a larger amount of tissue, thus potentially reducing the number of ablations. In addition, the cooling system was not used for the purpose of avoiding complications that might result from unexpected larger ablations using the cooling system. However, several authors reported OO-RFA procedures using the cool-tip electrode with the cooling system.[13,20] Martel et al. reported that the use of a 10-mm electrode with the cooling system could be responsible for a high success rate (97% primary and 100% secondary success rate) and a lack of relapses.[13] In our cases, there were two recurrences in patients who had relatively large nidi (15 and 23 mm, respectively). Vanderschueren et al. reported that multiple needle positions reduce the risk for treatment failure and should especially be used for lesions with a diameter of ≥10 mm. They also did not advocate the use of the cooling system because of safety considerations.[19] It is still controversial whether the cooling system should be used and what the length of the exposed tip should be.

Complications of RFA, such as skin burns, necrosis, fracture, and infection, have been reported in the literature; however, most authors have reported either no or only minor complications that did not require further treatment.[6–10,13] In our study, one patient with a lesion in the tibia developed pes equinus contracture/deformity following RFA through the posterior approach via the calf muscle. Functional recovery was observed after several days without further treatment. Applying RFA using the trans-calf muscle approach may cause temporary muscle damage, especially in young children.[21] A skin burn was found in one patient with a lesion in the tibia, whose soft tissue overlaying the lesion was very thin. After this case, we carefully measured the distance between the tip of the electrode and the skin surface to avoid a skin burn. This precaution has resulted in avoiding the same complication.

Histological confirmation of the diagnosis was attempted for all patients and yielded a firm diagnosis in 76.5% of patients, a rate higher than obtained by several authors.[6–8,10] The occurrence of a substantial number of nondiagnostic biopsy findings is not surprising given the small size of the needle specimen. Rosenthal et al. reported that most patients with nondiagnostic biopsy findings did in fact have OO, and nondiagnostic biopsy findings did not have a detectable effect on the probability of a successful outcome.[8]

This study had several limitations. The number of cases was small, and the study had a retrospective design. Therefore, we are now conducting a Phase I–II multiinstitutional prospective study of OO-RFA to evaluate the safety and efficacy of this treatment.

Conclusion

Computed tomography-guided percutaneous RFA is a simple, minimally invasive, safe, highly effective procedure for treating OO, and it should be considered as the procedure of choice in most patients with such tumors. It is still controversial whether the cooling system should be used and what the length of the exposed tip should be for this procedure. We believe that a well-designed, prospective study is needed to clarify the safety and efficacy of this treatment more precisely.

References

1. Helms CA, Hattner RS, Vogler JB 3rd. Osteoid osteoma: radionuclide diagnosis. Radiology 1984;151:779–84.
2. Kransdorf MJ, Stull MA, Gilkey FW, Moser RP Jr. Osteoid osteoma. Radiographics 1991;11:671–96.
3. Assoun J, Richardi G, Railhac JJ, Baunin C, Fajadet P, Giron J, et al. Osteoid osteoma: MR imaging versus CT. Radiology 1994;191:217–23.
4. Ehara S, Rosenthal DI, Aoki J, Fukuda K, Sugimoto H, Mizutani H, et al. Peritumoral edema in osteoid osteoma on magnetic resonance imaging. Skeletal Radiol 1999;28:265–70.
5. Rosenthal DI, Alexander A, Rosenberg AE, Springfield D. Ablation of osteoid osteomas with a percutaneously placed electrode: a new procedure. Radiology 1992;183:29–33.
6. Woertler K, Vestring T, Boettner F, Winkelmann W, Heindel W, Lindner N. Osteoid osteoma: CT-guided percutaneous radiofrequency ablation and follow-up in 47 patients. J Vasc Interv Radiol 2001;12:717–22.
7. Vanderschueren GM, Taminiau AH, Obermann WR, Bloem JL. Osteoid osteoma: clinical results with thermocoagulation. Radiology 2002;224:82–6.
8. Rosenthal DI, Hornicek FJ, Torriani M, Gebhardt MC, Mankin HJ. Osteoid osteoma: percutaneous treatment with radiofrequency energy. Radiology 2003;229:171–5.
9. Cioni R, Armillotta N, Bargellini I, Zampa V, Cappelli C, Vagli P, et al. CT-guided radiofrequency ablation of osteoid osteoma: long-term results. Eur Radiol 2004;14:1203–8.
10. Hoffmann RT, Jakobs TF, Kubisch CH, Trumm CG, Weber C, Duerr HR, et al. Radiofrequency ablation in the treatment of osteoid osteoma-5-year experience. Eur J Radiol 2009;73:374–9.
11. Rosenthal DI, Marota JJ, Hornicek FJ. Osteoid osteoma: elevation of cardiac and respiratory rates at biopsy needle entry into tumor in 10 patients. Radiology 2003;226:125–8.

12. Cribb GL, Goude WH, Cool P, Tins B, Cassar-Pullicino VN, Mangham DC. Percutaneous radiofrequency thermocoagulation of osteoid osteomas: factors affecting therapeutic outcome. Skeletal Radiol 2005;34:702–6.
13. Martel J, Bueno A, Ortiz E. Percutaneous radiofrequency treatment of osteoid osteoma using cool-tip electrodes. Eur J Radiol 2005;56:403–8.
14. Rimondi E, Bianchi G, Malaguti MC, Ciminari R, Del Baldo A, Mercuri M, et al. Radiofrequency thermoablation of primary non-spinal osteoid osteoma: optimization of the procedure. Eur Radiol 2005;15:1393–9.
15. Kjar RA, Powell GJ, Schilcht SM, Smith PJ, Slavin J, Choong PF. Percutaneous radiofrequency ablation for osteoid osteoma: experience with a new treatment. Med J Aust 2006;184:563–5.
16. Peyser A, Applbaum Y, Khoury A, Liebergall M, Atesok K. Osteoid osteoma: CT-guided radiofrequency ablation using a water-cooled probe. Ann Surg Oncol 2007;14: 591–6.
17. Sung KS, Seo JG, Shim JS, Lee YS. Computed-tomography-guided percutaneous radiofrequency thermoablation for the treatment of osteoid osteoma: 2 to 5 years follow-up. Int Orthop 2009;33:215–8.
18. Rosenthal DI, Hornicek FJ, Wolfe MW, Jennings LC, Gebhardt MC, Mankin HJ. Percutaneous radiofrequency coagulation of osteoid osteoma compared with operative treatment. J Bone Joint Surg Am 1998;80:815–21.
19. Vanderschueren GM, Taminiau AH, Obermann WR, van den Berg-Huysmans AA, Bloem JL. Osteoid osteoma: factors for increased risk of unsuccessful thermal coagulation. Radiology 2004;233:757–62.
20. Cantwell CP, O'Byrne J, Eustace S. Radiofrequency ablation of osteoid osteoma with cooled probes and impedance-control energy delivery. AJR Am J Roentgenol 2006;186:S244–8.
21. Shinozaki T, Sato J, Watanabe H, Takagishi K, Aoki J, Koyama Y, et al. Osteoid osteoma treated with computed tomography-guided percutaneous radiofrequency ablation: a case series. J Orthop Surg (Hong Kong) 2005;13:317–22.