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SCIENTIFIC ARTICLE

Radiofrequency ablation of chondroblastoma: procedure technique, clinical and MR imaging follow up of four cases

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Abstract
Purpose The aim of this study is to describe the procedure technique, clinical and imaging outcomes of patients treated with radiofrequency ablation for chondroblastoma.
Materials and methods Four patients (female/male, 3:1; mean age, 13 years; age range; 9–16 years) underwent the procedure. All had pre-operative magnetic resonance imaging (MRI) and symptomatic, biopsy-proven chondroblastomas (two proximal femur, two proximal tibia). The lesion size ranged from 1.5 to 2.5 cm in maximal dimension (mean size, 1.8 cm). Bone access was gained with a Bonopty biopsy needle system (mean number of radiofrequency needle placements, 5; mean ablation time, 31 min).
Results Clinical and MRI follow-up was available in all cases (mean, 12.25 months; range, 5–18 months). All patients reported resolution of symptoms at 2–6 weeks post ablation. At their most recent clinical follow-up, three patients remained completely asymptomatic with full return to normal activities and one patient had minor local discomfort (different pain pattern) that was not limiting activity. All four patients' follow-up MRI studies demonstrated resolution of the oedema pattern around the lesion and temporal evolution of the internal signal characteristics with fatty replacement.
Conclusion Radiofrequency ablation for chondroblastoma provides an alternative to surgical curettage, and we have demonstrated both a clinical improvement in symptoms and the follow-up MRI appearances.

Keywords Chondroblastoma · Radio-frequency ablation · Magnetic resonance imaging

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Introduction

Chondroblastoma is a rare, benign, cartilaginous tumour that accounts for approximately 1–2% of all benign bone tumours [1]. It is most frequent in the second and third decades, and is twice as common in males. It typically arises from the epiphysis or, less commonly, the apophysis of a long tubular bone (80%) where it occurs most often in the femur, followed by the humerus and tibia [2, 3]. Less common sites of involvement include the hands and feet (10%), craniofacial bones, spine, clavicle and sternum [3]. The clinical presentation is often non-specific with mild joint pain, and symptom duration can range from months to years [3]. Chondroblastomas do not spontaneously regress and standard treatment is surgical curettage.

Radiofrequency (RF) ablation was first described as a primary treatment for osteoid osteoma in 1992 and is now well established as the treatment of choice [4, 5]. It is a minimally invasive procedure with outcomes comparable to surgery but with faster recovery rates and fewer major complications [6]. It is a technique that is also being successfully applied in the management of painful skeletal metastases [5]. Recently, its use has also been described in the treatment of chondroblastomas [7, 8].

We report four cases of chondroblastoma treated by computed tomography (CT)-guided radiofrequency ablation at a single institution over an 18-month period. The initial presentation, procedure, clinical outcomes and follow-up

MR imaging is presented. Institutional approval was obtained prior to the first procedure being performed, and all cases were discussed both pre- and postoperatively at our multidisciplinary orthopaedic oncology meeting.

Material and methods

Study population and imaging findings

Four patients were treated over an 18-month period with radiofrequency ablation for chondroblastoma (female/male, 3:1). The mean age was 13 years (range, 9–16 years). The lesions were located as follows: two proximal femur and two proximal tibia. The lesion size ranged from 1.5 to 2.5 cm in maximal dimension (mean size, 1.8 cm). All patients had pre-procedural magnetic resonance imaging (MRI) demonstrating a focal epiphyseal lesion surrounded by bone marrow oedema. The typical presentation was of a chronic, non-specific aching pain in the affected area. Two patients underwent an initial CT-guided diagnostic biopsy at our institution, which confirmed chondroblastoma prior to RF ablation. In two cases, the imaging findings were thought to be sufficiently characteristic to proceed directly to RF ablation. Both cases were biopsied at the time of the procedure, which confirmed chondroblastoma.

During this 18-month interval, a total number of 12 patients with biopsy proven chondroblastoma were treated at our institution. Thirty-three percent were therefore treated with radiofrequency ablation with the remainder undergoing standard surgical curettage. The decision to proceed with radiofrequency ablation rather than open surgery was taken in consensus with our oncology surgeons taking into account the lesion size, location and potential surgical morbidity. It was decided that larger lesions (over 4 cm) would be best treated surgically as the RF time would be very long. Lesions that would be difficult to access surgically, for example, in the femoral head where disarticulation of the hip would be necessary, were deemed to be best treated by RF ablation.

Procedure technique

Parental/guardian consent was obtained prior to the procedure including the possibility of thermal injury to the growth plate and hyaline articular cartilage. All procedures were performed under general anaesthesia with the patient appropriately positioned on the CT table. A planning CT of the affected area was performed at 1 mm section thickness (Siemens four-channel multidetector CT) to allow planning for needle access. The skin, subcutaneous tissue and periosteum was infiltrated with 0.5% bupivicaine. Under aseptic technique and CT guidance, access was gained using the Bonopty coaxial bone biopsy system (Radi Medical Systems, Uppsala, Sweden). A 5–10 mm Neurotherm radiofrequency thermoablation electrode (sized according to individual case requirement) was then inserted into the tumour, and the lesion ablated with 3-min cycles at 90°C (Fig. 1). Multiple needle placements were required in all the lesions. In some cases, it was possible to place two needles concomitantly (Fig. 2). Particular care was taken when needle placement was near the joint surface or epiphyseal growth plate to ensure it was not included in the RF ablation field. Needle position and number of placements was determined by dividing the lesion into cubes using axial and longitudinal planes, the proportions of the cube depending upon the ablation zone of the RF electrode, thereby ensuring that the entire lesion was ablated. We worked in a cranial to caudal direction from personal preference. All patients were treated as day case procedures and discharged with appropriate analgesia. Table 1 illustrates the site and size of the lesion, number of needle placements required and radiofrequency ablation time for each patient.

Results

No complications were recorded. All patients reported resolution of symptoms between 2–6 weeks following ablation. The mean follow-up period was 12.25 months (range, 5–18 months). Table 2 illustrates the initial and post-procedure MRI findings and documents the post

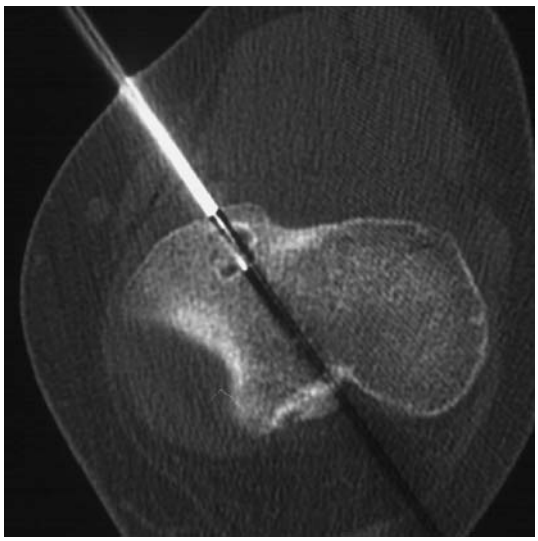

Fig. 1 Axial CT demonstrating the position of the radiofrequency ablation needle in the lesion

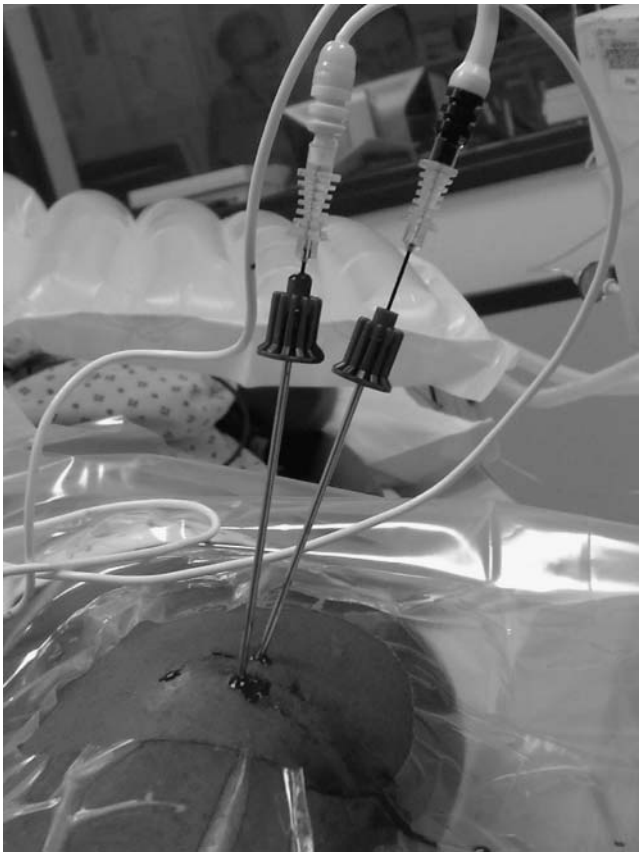

Fig. 2 Photograph demonstrating concomitant placement of two radiofrequency ablation needles within lesion

procedure resolution of symptoms. MRI sequences consisted of T1-weighted sagittal and axial, and inversion recovery sagittal and T2 fat-saturated axial images. No post-contrast imaging was performed. Figures 3 and 4 demonstrate the pre- and post-MRI findings. Three patients remained symptom-free and had returned to full activities. Pain was assessed subjectively by asking patients about their symptoms in clinic. One patient had a good initial improvement in symptoms for the first month but developed some minor local discomfort. The pain pattern was different from her presentation, and it did not limit her activities of daily living, and at 14 months, she had only occasional mild pain.

Discussion

Chondroblastoma is a rare, benign cartilaginous tumour, the imaging findings of which are highly characteristic. These consist of a well-defined, oval, lytic lesion less than 6 cm in size, centrally or eccentrically placed in the epiphysis or apophysis of a skeletally immature patient [2, 3]. MR imaging demonstrates low to intermediate signal on T1-weighted images and intermediate to low signal on T2-weighted images. On fat-suppressed and inversion recovery sequences, there is often a surrounding rim of high signal corresponding with bone marrow oedema and a joint effusion [2, 3]. The presence of bone marrow oedema is thought to correlate with pain and resolves following successful surgical treatment [2].

Treatment of chondroblastomas has traditionally consisted of surgical curettage followed by packing with bone graft or bone cement (polymethylmethacrylate) or local cryotherapy [9, 10, 11]. This has a reported recurrence rate of between 10–35% [6]. In view of the classic epiphyseal location of this tumour, surgical treatment may be problematic. Curettage may damage the growth plate, resulting in growth arrest and limb length discrepancy. The overlying articular cartilage can also be damaged, causing premature osteoarthritis [11, 12] All these complications may result in a poor functional outcome.

RF ablation is a minimally invasive technique that selectively destroys a small volume of tissue. It causes tissue necrosis by thermal coagulation. Essentially an RF electrode is an uninsulated length of wire that, when connected to a generator, rapidly changes its polarity, causing rapid oscillation in surrounding particles, thereby generating heat. The RF electrode is a monopole emitter of energy, and this fact in combination with the fact that most tissue conductivity is very similar means that the ablation zone is almost spherical. In other words, a 5-mm exposed tip RF electrode will have an approximately 1 cm spherical burn zone [5]. As such, it is ideal for treating small tumours of bone and has been used very successfully for many years to treat osteoid osteomas [5, 13].

There is increasing interest in using this technology to treat other musculoskeletal tumours, in particular chondroblastomas. The authors are aware of three previous reports

Table 1 The site and size of the lesion, number of needle placements required and radiofrequency ablation time for each patient

Patient	Site	Size of lesion (cm)	Number of needle placements	Radiofrequency ablation time (min)	Follow-up period (months)
1	Left proximal femoral epiphysis	1.5×1.5	4	24	14
2	Right proximal femoral epiphysis	2×2	5	39	12
3	Left proximal tibial epiphysis	1.2×1	2	12	18
4	Right proximal tibial epiphysis	2×2.5	10	48	5

Table 2 The initial and post-procedure MRI findings and the post-procedure resolution of symptoms

Patient	Pre RF MRI	Post RF MRI	Symptoms
1		4 weeks post RF:	4 weeks post RF:
	Moderate sized hip effusion	No change in appearance of hip effusion, lesion or bone marrow oedema	Pain improving
	1.5 cm lytic lesion in proximal femoral capital epiphysis extending to articular cartilage	4 months post RF:	4 months post RF:
		Diminished size of hip effusion	Pain-free
	Patchy oedema of femoral neck	Unchanged appearance of lesion and bone oedema	
		10 months post RF:	9 months post RF:
		No hip effusion	Asymptomatic with full return to normal function
		Lesion demonstrates in filling with fat on T1-weighted images	
		Minimal bone marrow oedema	
2	Small hip effusion	4 months post RF:	4 months post RF:
		No hip effusion	Pain-free
	2×2 cm focal lytic lesion in proximal femoral epiphyses	Lesion shows in growth of marrow fat around margins on T1-weighted images	
	Extensive surrounding bone marrow oedema	No residual oedema	
			7 months post RF:
			Asymptomatic with full return to normal function
3		6 months post RF:	6 weeks post RF:
	1.2×1 cm lytic lesion in proximal tibial epiphyses	Patchy in-growth of normal fatty marrow into lesion on T1W images	Initial pain improvement at 3 weeks. Mild pain at 6 weeks but different pain pattern
	Extensive surrounding bone marrow oedema	No bone marrow oedema	
		14 months post RF:	14 months RF:
		Extremely small focus high of signal change on T1W at site of previous lesion	Occasional mild pain but with full return to normal function
		No residual oedema	
4		3 months post RF:	3 months post RF:
	2×2.5 cm lytic lesion in proximal tibial epiphyses	Edge of the lesion demarcated by a low signal rim with an underlying rim of high signal on T1-weighted images. This represents in-growth of marrow fat with surrounding medullary bone	Completely asymptomatic at 2 weeks post-procedure with full return to normal function. Remains symptom-free at 3 months
	Moderate degree of surrounding bone marrow and soft tissue oedema		
		No adjacent bone marrow oedema seen	

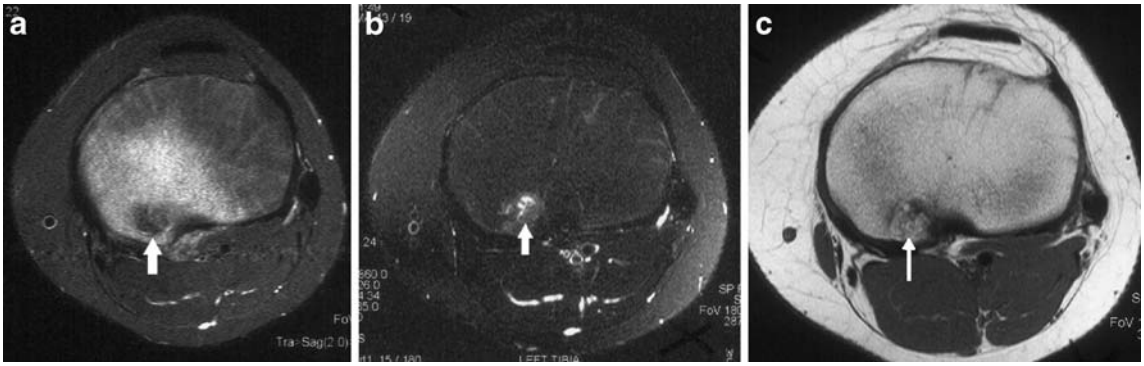

Fig. 3 **a** Pre-RF axial T2 fat saturation, demonstrating chondroblastoma (*arrow*) in proximal tibial epiphysis with surrounding bone marrow oedema. **b** Axial T2 fat saturation 6 months post RF ablation, demonstrating resolution of bone marrow oedema. Arrow pointing to chondroblastoma. **c** Axial T1 6 months post RF ablation demonstrating in-growth of fat (*arrow*) into site of previous lesion

and one scientific presentation regarding the treatment of chondroblastomas with RF ablation. Erickson and co-workers described successful CT-guided RF ablation of three chondroblastomas. In their series, they used the same standard treatment method as is used to ablate osteoid osteomas, i.e. a single RF electrode heated to 90°C for two cycles of 3 min. The average lesion size ablated in their series was 1.4 cm. The first case was in the head of the femur, the second in the proximal medial tibial epiphyses and the third in the lateral femoral condyle. The first case was only 8 mm in diameter and was initially thought to be an osteoid osteoma. This was ablated with a single treatment. The subsequent two cases were all diagnosed chondroblastomas, and all required multiple needle placements. The average number of needle placements was three, and the average total ablation time was 20 min. Patients were followed up clinically and by radiographs or CT. Follow-up imaging demonstrated a decrease in the size of the lesion and a sclerotic healing zone around the lesion periphery at 2 months post-procedure (seen in one case on CT). All patients reported complete resolution of symptoms, and no complications were recorded [7].

Tins and co-workers described four chondroblastomas treated by CT-guided RF ablation. In their series, they used a multi-tined expandable electrode more commonly used to treat liver and renal lesions. The average size of a lesion treated in their series was 3.3 cm (using the maximum measurement), yet they had only an average of three needle placements per case because of the larger burn zone of the multi-tined electrode. At each placement, the system was set to heat to 90°C for 5 min, giving an average total ablation time of 15 min. Lesions were located in the greater tuberosity of the humerus, the lateral femoral condyle and two within the proximal tibial epiphysis. Cases were followed up clinically initially 3 monthly and then 6 monthly for an average of 1 year and 6 months. Follow-up imaging using a combination of radiographs, CT and MRI was only performed in those patients with persisting clinical symp-

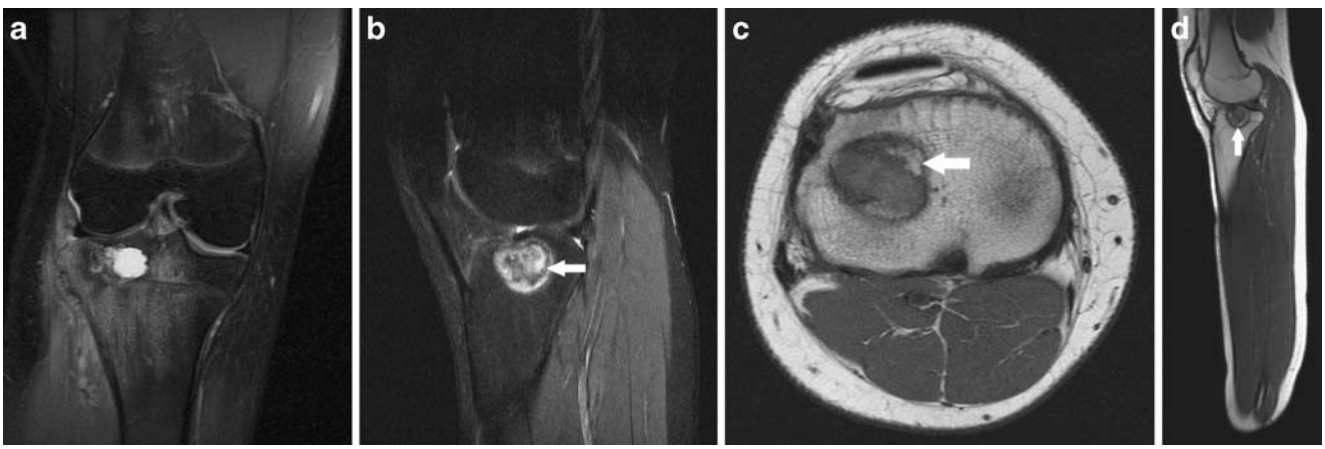

Fig. 4 **a** Pre-RF coronal T2 fat saturation demonstrating chondroblastoma in proximal tibial epiphysis with surrounding bone marrow oedema. **b** T2 fat-saturated sagittal image 3 months post RF ablation, demonstrating resolution of bone marrow oedema. *Arrow* points to low signal fatty in-growth. **c** and **d** T1 axial and T1 sagittal images 3 months after RF ablation, demonstrating in-growth of fat (*arrows*) into site of previous lesion

toms. Complications occurred in two cases (50%)—infraction of a subarticular chondroblastoma in one case and damage to the cartilage and bone in the knee compartment not containing the lesion in the other [8].

Petsas and co-workers recently described two cases of femoral head chondroblastomas (average size, 2.7 cm) treated by a combination of curettage and radiofrequency ablation followed by apposition of bone graft. In their series, access to the lesion was obtained by fluoroscopic guided drilling along the femoral neck. The lesion was then partly curettaged and the sample sent to histology. A 15G 12-cm multi-tined expandable RF probe with a burn zone of 2 cm was then inserted into the lesion, and ablation was performed for 5 min at 85–90°C. Two needle placements were required for each lesion, giving a total ablation time of 10 min per lesion. Following ablation, bone graft was inserted into the bone defect. All patients reported immediate improvement in pain. Imaging follow-up was performed by means of radiographs and CT at 1 year post-procedure and demonstrated reduced size and increased sclerosis of the lesion. No complications were reported [14]. Finally, at a presentation given at the 2007 Radiological Society of North America annual meeting, Rybak and co-workers discussed their experience treating 14 chondroblastomas in 13 patients with RF ablation, using a single-tip, monopolar electrode. Twelve out of 13 patients had significant pain relief within 24 h of the procedure. The only patient who did not experience pain relief was subsequently discovered to have developed a subchondral fracture—the only complication in the series [15].

We used a similar method to that used by Erickson and co-workers, namely a single RF electrode placed multiple times within the lesion. We had 1.6 times the number of needle placements as used by Erickson and co-workers; however, our average lesion size was 1.3 times larger than theirs. We had an average total ablation time of 31 min per case. Tins and co-workers had half the number of needle placements and half the ablation time, despite the larger average lesion size in their series. However, we had fewer complications than experienced in their series. Petsas and co-workers used a combined surgical/RF approach. As a result, in their series, access to the lesion was gained in a much more invasive manner by drilling along the femoral neck, whereas we accessed the lesions in the femoral head via a 12G bone biopsy needle under CT guidance. It is difficult to determine the efficacy of RF ablation alone in their study because of their concomitant use of curettage and bone grafting. Lastly, it is impossible to determine if the appearances on the follow-up CTs in their series are because of lesion healing post-RF or because of amalgamation of bone graft into the lesion.

One of the greatest concerns in treating chondroblastomas—whether surgically or by ablation—is damage to the hyaline articular cartilage. This is particularly important when performing ablation next to the subchondral bone plate and the potential for articular cartilage injury. Martel and co-workers looked at the relationship between RF probe type (cooling or non-cooling) and procedure time on length and extent of osteonecrosis in dog long bones. Single RF electrodes were used. They found that intact cortical bone had a protective affect and prevented damage to overlying articular cartilage, even if the RF electrode tip was very close to the joint surface and the cartilage lay in the predicted RF burn zone. The type of probe used, size of lesion and duration of RF ablation did not result in any difference [16]. The cortical bone overlying chondroblastomas may not always be intact. Prior knowledge of this may alert the operator to an increased potential for articular cartilage damage if RF ablation is performed. If the cartilage is intact, the exposed tip of the RF electrode could be placed closer to the joint surface if necessary. We surmise that the complication rate experienced by Tins and co-workers was as a result of their use of a multi-tined electrode. While this diminishes total RF time, it does have a larger burn zone resulting in increased likelihood of damage to surrounding structures. We believe that use of a single RF electrode, whilst more time consuming as several needle placements will be required to completely ablate the tumour, allows for a more controlled burn zone.

To the best of our knowledge, there is no published information regarding the MR appearances of successfully treated chondroblastomas with radiofrequency ablation. No doubt this is because this is a new technique. Initially, we identified a reduction in size and eventual resolution of the joint effusion if present. Subsequently, on T1-weighted sequences, a high signal rim developed around the periphery of the lesion. This high signal area gradually began to in-fill into the lesion, and we assume that it represents in-growth of marrow fat and hence the start of healing. In one case, a low signal rim was seen outside of the high signal area on T1 images, which we think represents a small rim of sclerotic bone and further evidence of healing. One of the most sensitive indicators of successful treatment that we found was the gradual reduction in surrounding bone marrow oedema on T2 fat-suppressed and inversion recovery sequences that was present before treatment. This does contrast somewhat with the pattern seen in post-RF ablation MRI of osteoid osteomas, where bone marrow oedema can remain present despite complete resolution of symptoms [17, 18].

There are a number of limitations inherent in this study. Firstly, the number of patients treated was small. This is primarily because of the rare nature of the tumour and relative infancy of the technique. Secondly, our mean follow-up is 12.25 months with a range of 5–18 months. Whilst we have demonstrated both clinical improvement in symptoms and MR imaging evidence of resolution, we

cannot comment on any potential recurrence rates in view of the short follow-up period. Chondroblastoma typically recurs within 10 months of treatment [10] and longer term follow-up of patients treated with this method will be required to formally assess the recurrence risk. We do, however, believe that RF ablation for chondroblastomas is a safe technique. With careful patient selection and use of single RF electrodes, complications can be minimized, and our experience suggests this may become an important method of treating this benign bone tumour.

References

1. Campanacci M. Bone and soft tissue tumours: clinical features, imaging, pathology and treatment, 2nd ed. New York: Springer; 1999. p. 247–264.
2. Resnick D. Diagnosis of bone and joint disorders, 4th ed. WB Saunders Company: Philadelphia; 2002. p. 3850–3866.
3. Stoller DW, Tirman PFJ, Bredella MA. Diagnostic imaging in orthopaedics. Salt Lake City: Amirsys; 2004. p. 26–28.
4. Rosenthal D, Alexander A, Rosenberg AE, Springfield D. Ablation of osteoid osteomas with a percutaneously placed electrode: a new procedure. Radiology 1992; 183: 29–33.
5. Rosenthal D. Radiofrequency treatment. Orthop Clin N Am 2006; 37: 475–484.
6. Rosenthal DI, Hornicek FJ, Wolfe MW, Jennings LC, Gebhardt MC, Mankin HJ. Percutaneous radiofrequency ablation of osteoid osteoma compared with operative treatment. J Bone Jt Surg Am 1998; 80: 815–821.
7. Erickson JK, Rosenthal DI, Zaleske DJ, Gebhardt MC, Cates JM. Primary treatment of chondroblastoma with percutaneous radiofrequency heat ablation: report of three cases. Radiology 2001; 221: 463–468.
8. Tins B, Cassar-Pullicino V, McCall I, Cool P, Williams D, Mangham D. Radiofrequency ablation of chondroblastoma using a multi-tined expandable electrode system: initial results. Eur Radiol 2006; 16: 804–810.
9. Van Der Geest IC, Van Noort MP, Schreuder HW, Pruszczynski M, De Rooy JW, Veth RP. The cryosurgical treatment of chondroblastoma of bone: long term oncologic and functional results. J Surg Oncol 2007; 96(3): 230–234.
10. Suneja R, Grimer RJ, Belthur M, et al. Chondroblastoma of bone: long-term results and functional outcome after intralesional curettage. J Bone Jt Surg Br 2005; 87(7): 974–978.
11. Ramappa AJ, Lee FYI, Tang P, Carlson JR, Gebhardt MC, Mankin HJ. Chondroblastoma of bone. J Bone Jt Surg Am 2000; 82A: 1140–1145.
12. Springfield DS, Capanna R, Gherlinzoni F, Picci P, Campanacci M. Chondroblastoma: a review of seventy cases. J Bone Jt Surg Am 1985; 67: 748–755.
13. Davis KW, Choi JJ, Blankenbaker DG. Radiofrequency ablation in the musculoskeletal system. Semin Roentgenol 2004; 39: 129–144.
14. Petsas T, Megas P, Papathanassiou Z. Radiofrequency ablation of two femoral head chondroblastomas. Eur J Radiol 2007; 63: 63–67.
15. Rybak LD, Rosenthal DI, Wittig J. Radiofrequency ablation of chondroblastomas: an alternative to surgical resection in selected cases. A presentation at RSNA 2007 (abstract).
16. Martel J, Bueno A, Dominguez MP, Llorens P, Quiros J, Delgado C. Percutaneous radiofrequency ablation: relationship between different probe types and procedure time on length and extent of osteonecrosis in dog long bones. Skeletal Radiol 2008; 37: 147–152.
17. Vanderscheuren GM, Taminiau AHM, Obermann WR, van den Berg-Huysmans AA, Bloem JL, van Erkel AR. The healing pattern of osteoid osteomas on computed tomography and magnetic resonance imaging after thermocoagulation. Skeletal Radiol 2007; 36: 813–821.
18. Lee MH, Ahn JM, Chung HW, et al. Osteoid osteoma treated with percutaneous radiofrequency ablation: MR imaging follow up. Eur J Radiol 2007; 64(2): 309–314.