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INTERVENTIONAL

Radiofrequency ablation of chondroblastoma: long-term clinical and imaging outcomes

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Abstract
Objectives To investigate the long-term clinical and imaging outcomes of patients with chondroblastoma treated by radiofrequency ablation (RFA).
Methods Retrospective analysis of 25 consecutive patients treated with RFA from September 2006 to December 2013. Patients were reviewed within one month of the procedure, then every 3-6 months, and yearly for up to three years. Serial magnetic resonance imaging (MRI) was performed at follow-up to monitor recovery. Functional outcome was assessed using the Musculoskeletal Tumour Society Score (MSTS).
Results Pre-procedure MRI confirmed osteolytic lesions (size range 1.0-3.3 cm; mean 2.0 cm). Patients reported continued symptomatic improvement at four months review. Serial MRI confirmed progressive resolution of inflammation with fatty consolidation of cavity. 88 % of patients became asymptomatic during the follow up period. Three patients' (12 %) symptoms returned at 16, 22 and 24 months respectively after RFA. MRI and biopsy confirmed recurrence in these patients. Functional assessment using MSTS score had an average score of 97.5 %. Mean follow up for the study group was 49 months.
Conclusion RFA is an effective alternative to surgery in the management of chondroblastoma. We recommend a multidisciplinary approach and RFA should be considered as a first-line treatment. Long-term follow-up is required for timely detection of recurrences.

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Key Points
- *RFA is a safe and effective technique in the treatment of chondroblastoma.*
- *Positive outcomes in 88 % patients at mean follow-up period of 49 months.*
- *Local recurrences occurred in 12 % cases.*
- *Long-term follow-up is required for timely detection of recurrences.*
- *RFA should be considered as a first-line treatment for chondroblastoma.*

Keywords Chondroblastoma · Radiofrequency ablation · Magnetic resonance imaging · Recurrence

Introduction

Chondroblastomas are a primary cartilaginous bone tumour that accounts for 1 % of all benign bone tumours [1]. They normally affect the epiphysis and occasionally the apophysis of long bones and are rarely encountered in the hands and feet. The condition occurs more commonly in males in their second and third decades of life [2]. Patients usually present with non-specific joint pain with between months to years of duration. Unfortunately, chondroblastomas do not spontaneously regress, and traditionally the standard treatment is surgical curettage [2, 3].

Complete surgical resection of the tumour can be difficult to achieve given the epiphyseal location of chondroblastomas. There is, therefore, a risk of tumour recurrence (8-20 % in surgically treated patients), and articular cartilage damage with the potential for premature osteoarthritis [3, 4].

An alternative treatment is percutaneous radiofrequency ablation (RFA). RFA has become a routine treatment for osteoid osteoma, and it is increasingly used for the palliation of painful bone metastases [5–7]. In recent years, a series of

reports on selected cases of chondroblastomas treated by RFA have shown positive results mostly in the short term [8–12]. Due to the rarity of the condition and recent introduction of this technique, there is limited evidence on the long-term outcomes following this procedure. The aim of this study was to investigate the long-term clinical and imaging outcomes of patients with chondroblastoma treated by RFA.

Materials and methods

Institutional approval was obtained for the retrospective analysis of clinical and imaging data used in this study.

Study population

Our institution is a tertiary referral centre for orthopaedic oncology cases. Twenty-five patients (15 male, ten female) were treated with RFA at our Centre from September 2006 to December 2013. This included 23 new cases without prior surgical management and two recurrent cases, which had surgical curettage before their referral for RFA. The mean age was 14 years (range 9-18 years). The maximal diameter of the lesions ranged from 1.0-3.3 cm (mean size, 2.0 cm). Lesions with a maximal dimension in excess of 3.5 cm on preoperative imaging were not treated with RFA. This was an arbitrary figure chosen by the senior author at the time of referral, which took into account the overall volume of tumour that needed to be ablated. Any patients not treated with RFA underwent standard surgical treatment and were not considered further with regard to this study.

All the patients presented with chronic non-specific pain with reduced range of movement and occasional swelling of the affected joint. The tumours were located at the proximal tibia (eight cases), proximal femur (seven cases), proximal humerus (four cases), distal femur (three cases), distal tibia (one case), distal radius (one case), and talus (one case).

Preoperative magnetic resonance imaging (MRI) demonstrated findings that were consistent with chondroblastoma in all cases – a focal lesion with surrounding bone marrow oedema and associated joint effusion (Figs. 1a, b and 3a, b). For histological confirmation of the diagnosis, a biopsy of the lesion was taken during the RFA procedure. All patients were discussed at an orthopaedic oncology multidisciplinary meeting that included orthopaedic oncology surgeons, pathologists, oncologists, and radiologists. The decision to proceed to RFA was made following discussion at the meeting and took into account lesion location, size, and potential surgical morbidity if curettage was to be undertaken as an alternative.

Procedure technique

Informed consent was obtained from the parents due to the young study population. One senior radiologist with extensive experience in RFA performed all the procedures. All procedures were performed under general anaesthesia and computed tomography (CT) guidance was routinely used. CT images were taken at 1 mm section thickness limited to the affected area with a skin marker grid applied prior to imaging. These images were analysed in the axial, coronal, and sagittal planes to give an overall appreciation of the tumour volume that required ablation. Initially, the anterior to posterior size of the lesion was measured on axial CT images. This enabled an appropriate ablation needle length to be chosen. The exposed needle tip lengths varied from 5-20 mm and ablation zones were planned according to the manufacturer's recommendations. Following this, the medial to lateral size of the lesion was measured on axial CT to give an indication of the number of needles that would be required in this direction. Most frequently, this required two parallel needles placed 1 cm apart, which provided an ablation width of 2 cm (Fig. 2a, b). The axial images were scrolled 1 cm in a cranial or caudal direction to give the next level to be treated, and the same process was repeated. The most proximal and distal needle placements were 5 mm from the proximal or distal extent of the lesion. The appropriate skin entry sites were then marked prior to skin sterilisation. Local anaesthetic (0.5 % bupivicaine) was administered to the insertion site before needle access with the Bonopty coaxial bone biopsy system (Apriomed, Uppsala, Sweden). A biopsy was performed as this stage for subsequent histological confirmation. Up to three simultaneous needles were inserted using three separate Bonopty needles. Subsequently, a Neurotherm (Wilmington, Massachusetts, USA) RFA system was used. Ablations were performed with up to three needles simultaneously for 6 minutes at 90 degrees Celsius. For larger lesions, a second and, if required, a third RFA was performed once the needles had been placed. It is extremely important that accurate needle placement was undertaken to ensure needle tracks followed the planned route on the preprocedure CT scan. The total number of needle positions per patient ranged from 1-12 sites (mean 4.1). Total ablation time ranged from 6-72 minutes (mean 24 minutes). Most commonly a combination of 10 mm or 15 mm exposed tips was utilised.

All the patients were treated as a day case or with overnight admission and discharged with adequate analgesia with initial follow-up within one month.

Follow-up procedure

A series of surgical outpatient follow-ups were planned for each patient. Patients' symptoms (joint pain, stiffness, weakness, and limitations in performing daily activities) were reviewed routinely in clinic within one month of the procedure, then every 3-6 months, and yearly. Additional follow-ups were conducted for patients that had concerns or recurring symptoms before their next appointment.

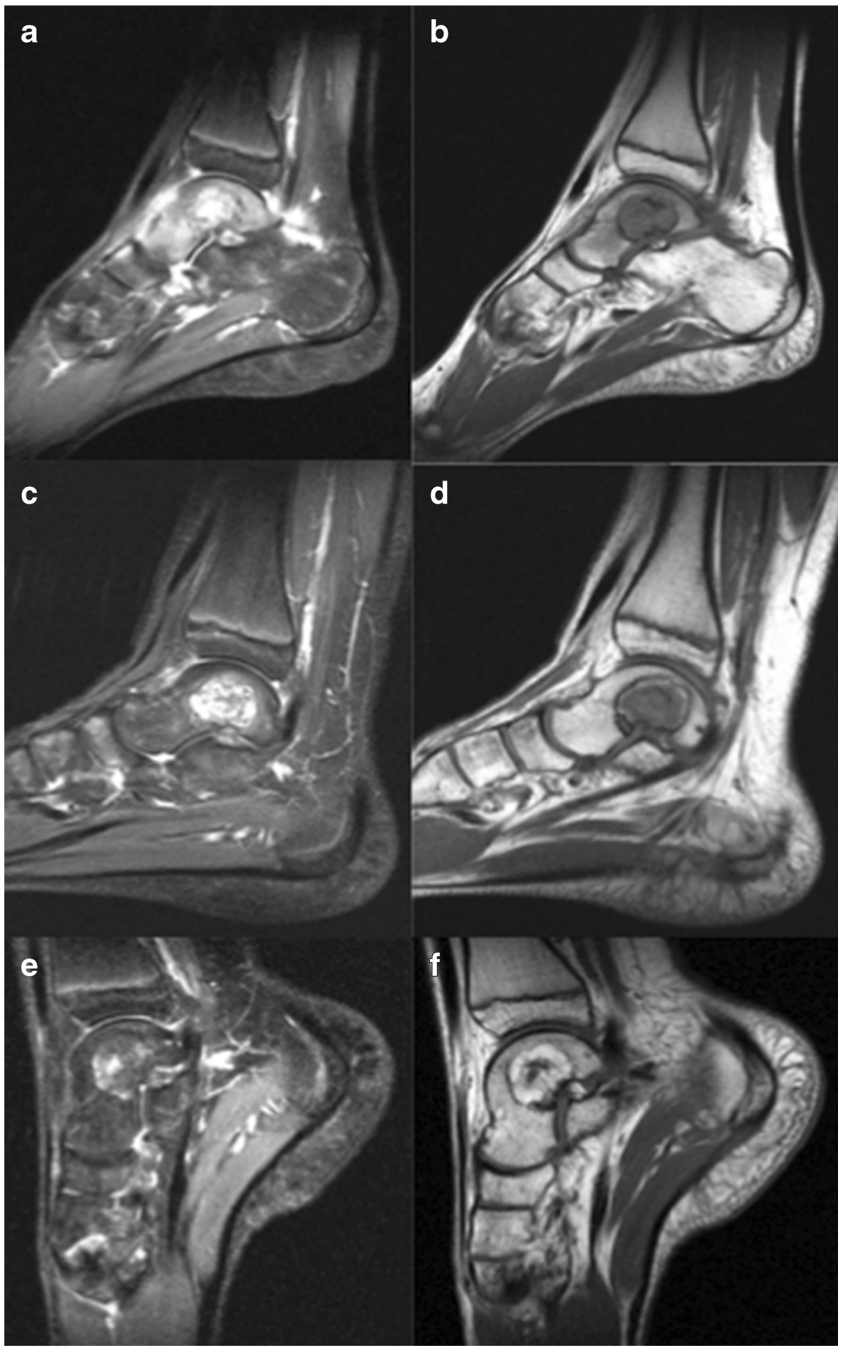

Fig. 1 **a** and **b** Preprocedure MRI: Sagittal T1 weighted and STIR sequences, respectively, demonstrate a well-demarcated lesion with a sclerotic margin in the talus with surrounding bone marrow oedema and associated joint effusion. **c** and **d** Six months post-RFA MRI: Sagittal T1-weighted and STIR sequences, respectively, show a significant reduction in the degree of peri-lesional oedema and that the joint effusion had resolved. There is a peripheral rim of fat suggesting early consolidation. **e** and **f** Fifteen months post-RFA MRI: Sagittal T1-weighted and STIR sequences, respectively, show progressive fatty consolidation of the lesion. No subchondral collapse or effusion in the ankle joint was identified

All patients had magnetic resonance imaging (MRI) including T1-weighted, and inversion recovery (STIR) sequences in three orthogonal planes as a minimum during follow-up studies. When patients had remained symptom-free for one year under our care, they were discharged back to their local surgical team or general practitioner for further follow-up.

At the time of preparation of this manuscript, a telephone interview was conducted using the Musculoskeletal Tumour Society Score (MSTS Score, Table 1) to provide a further functional outcome measurement in addition to the serial surgical follow-ups after tumour treatment [13].

Results

From September 2006 to December 2013, 25 patients with chondroblastoma were treated by RFA at our institution. All patients reported improvement in symptoms within 1 week of RFA with continued improvement at 4-months review. No

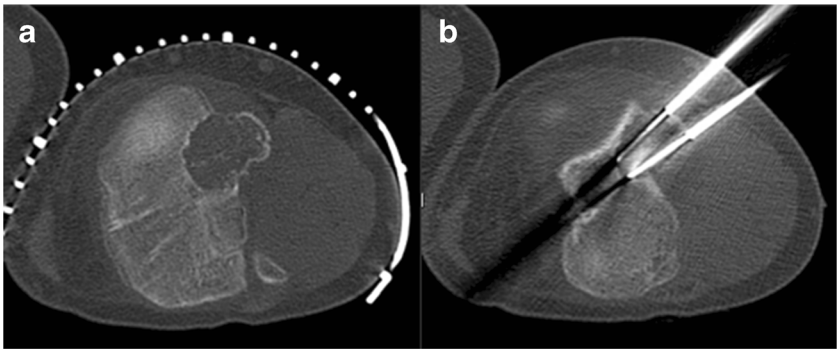

Fig. 2 **a** Intraoperative CT guided radiofrequency ablation of chondroblastoma. An irregular osteolytic lesion with subtle chondroid matrix was identified measuring 2.5×2.2×1.9 cm at the proximal tibial epiphysis. **b** Intraoperative CT-guided radiofrequency ablation of chondroblastoma with simultaneous insertion of two needle tips

immediate complications were noted. At three months following the procedure, the first MRI follow-up was acquired. These images demonstrated significant reduction of the bone marrow oedema surrounding the lesion and the adjacent reactive joint effusion was reduced. There was evidence of fatty consolidation in the cavity of the ablated site (Fig. 3c, d). Serial MRI follow-ups at 6 months and 12 months postprocedure showed progressive resolution of oedema, synovitis, and further fatty consolidation of the cavity. The follow-up MRI did not show evidence of subchondral collapse or osteonecrosis (Figs. 1 and 3). After 1 year of follow-up, 12 patients were free of symptoms, and they were able to carry out daily activities without any limitations. These patients were discharged back to their local surgical team or general practitioner for further monitoring. No further MRI images were taken of these patients at our institution due to clinical and imaging evidence of successful treatment. The remaining patients received ongoing follow-up with physiotherapy at our institution to help build muscle bulk and improve functionality of the affected limb. Within this group, five patients were discharged after 2 years; three patients were discharged after 3 years of monitoring. These patients underwent ongoing MRI follow-up every 12 months; this showed no evidence of oedema or joint effusion, and most cases had complete consolidation of the ablated site (Figs. 1e, f and 3g, h). Two patients had just completed their 6-month follow-up at the time of the study, and they will be reviewed in another 6 months.

Three of the 25 (12 %) patients' symptoms returned at 16, 22, and 24 months after their RFA treatment. These patients reported intermittent joint pain. In all three cases their initial MRI studies had suggested a response with an initial reduction of joint effusion and peri-lesional oedema. Subsequently, MRI showed a return of the peri-lesional oedema and joint effusions in all cases, and biopsy confirmed local recurrence in these patients. One patient had repeat RFA treatment and symptoms resolved after 9 months. Two patients were treated by curettage. This included a patient who had local recurrence previously after 6 months of having curettage before the RFA. This patient's symptoms slowly resolved after 14 months following repeat curettage.

The telephone follow-up using the MSTS score conducted at the time of preparation of this manuscript provided the final functional assessment. Depending on the individual patient, this interview was carried out between 12 months to 7.1 years after the RFA procedure with a mean follow-up time of 49.2 months. The average score was 97.5 % (range, 83-100 %). All the patients were satisfied at the outcome of the procedure. They were able to perform their daily activities including exercise without restrictions. Six patients described occasional joint pain after exercise but did not require analgesia. Two patients expressed emotional impact due to limitations on pursuing professional sporting careers. Four patients were unable to be contacted for the telephone follow-up.

Discussion

Surgical curettage has been considered the standard treatment for chondroblastoma, but it has recognised risks and complications. The reported recurrence rate in surgically treated patients can be up to 20 %. Curettage has the risk of damaging the articular cartilage or the growth plate, which may result in early-onset osteoarthritis or growth disturbance, respectively [3, 4]. Consequently, this makes RFA in the treatment of chondroblastoma a potentially attractive alternative.

The results of our study provide further evidence to support the use of RFA as another option to surgery. Following RFA, symptomatic improvements were seen in all patients within 1 week and they became symptom-free within 4 months. Hence, the short-term benefit of pain relief in our patients was 100 % (25/25). Ongoing surgical follow-up supported by serial MRI findings for up to 3 years demonstrated continuous improvements both symptomatically and structurally in 88 % (22/25) of patients. Additional assessment in the form of telephone interviews specifically tailored to evaluate joint

Table 1 Components of the Musculoskeletal Tumour Society Score (MSTS Score) for the telephone interview

		Score
Pain (upper/lower limb)		
None		5
Intermediate		4
Modest/non-disabling		3
Intermediate		2
Intermittently disabling		1
Continuously disabling		0
Function (upper/lower limb)		
No restrictions		5
Intermediate		4
Recreational restrictions		3
Intermediate		2
Partial occupational disability		1
Total disability		0
Emotional acceptance (upper/lower limb)		
Enthused		5
Intermediate		4
Satisfied		3
Intermediate		2
Accepts		1
Dislikes		0
Walking ability (lower limb)	Hand positioning (upper limb)	
Unlimited	Unlimited	5
Intermediate	Intermediate	4
Limited	No pro- or supination	3
Intermediate	Intermediate	2
Inside only	Not above wrist	1
Not independent	None	0
Gait (lower limb)	Dexterity (upper limb)	
Normal	Unlimited	5
Intermediate	Intermediate	4
Minor cosmetic	Loss of fine movements	3
Intermediate	Intermediate	2
Major cosmetic	Cannot pinch	1
Major handicap	Cannot grasp	0
Supports	Lifting ability (upper limb)	
None	Normal	5
Intermediate	Intermediate	4
Brace	Limited	3
Intermediate	Intermediate	2
Crutch	Helping only	1
Crutches	Cannot help	0

function offered up to 7.1 years for follow-up (mean 49.2 months). The positive response from patients and the average MSTS score of 97.5 % in 21 patients (four lost to follow-up) reaffirmed the persistent effectiveness of RFA in the treatment of chondroblastoma. This study also demonstrates the long-term results of this technique, which take into account a functional assessment of patient outcome as well as risk of locally recurrent disease.

In our study, there were three recurrences (12 %, 3/25) following RFA. Two patients were new cases, where RFA was the initial treatment technique. Review of the imaging of these patients to try and understand why recurrences occurred was undertaken. In the first case, the lesion was in the posterior portion of the proximal tibia, and the authors can see no specific reason why treatment was ineffective in this instance. The second case demonstrated the chondroblastoma within the intercondylar region of the knee. The authors suspect that the tumour was incompletely ablated due to the complexity of the anatomy of the trochlea groove. The final patient had previous curettage 6 months prior to RFA, and was referred to us with recurrent disease. Incomplete tumour ablation may have occurred in this case due to possible postsurgical changes from prior curettage that had led to underestimation of the margins of the recurrent tumour.

A case of tumour recurrence has previously been reported by Rybak and coworkers in their series of 17 patients treated by RFA [12]. This study highlighted the potential for recurrence following RFA, and the need for long-term follow-up. The current recommendation for surgical patients is yearly review for a minimum of 5 years [2, 14, 15]. In our study, the latest time of tumour recurrence was 24 months. Given the relatively small numbers of patients with recurrent disease identified in this rare tumour group, it would seem reasonable to follow patients for a longer period (instead of 2 years) with this new and evolving technique. Follow-up should, however, be more rigorous during the first 2 years following treatment as risk of recurrence is higher during this time.

The lesions that were treated in our study were anatomically distributed mainly at the epiphysis of long bones (humerus, femur, and tibia), but we also had three less common cases in the distal tibia, distal radius, and talus. In addition, the size of the lesions presented in our study had an average diameter of 2.0 cm, which is relatively larger than the lesions treated by RFA in previous series with mean diameters of 1.8 cm [11] and 1.4 cm [12]. We report no immediate complication as a direct result of the procedure, and ongoing follow-up with additional functional assessment demonstrated positive outcomes for all the patients in the long-term.

While current experience with smaller lesions has shown encouraging results, cases of larger tumours treated by RFA have demonstrated the possibility of damage to the articular surface. In the small series by Tins and coworkers [9], the average lesion size was 3.3 cm, two of the four cases that had lesions up to 4.8 cm at the proximal tibial epiphysis developed complications of chondrolysis, osteonecrosis, and collapse at the tibial plateau above the treatment area. One of the contributors to the complications may have been lesion size

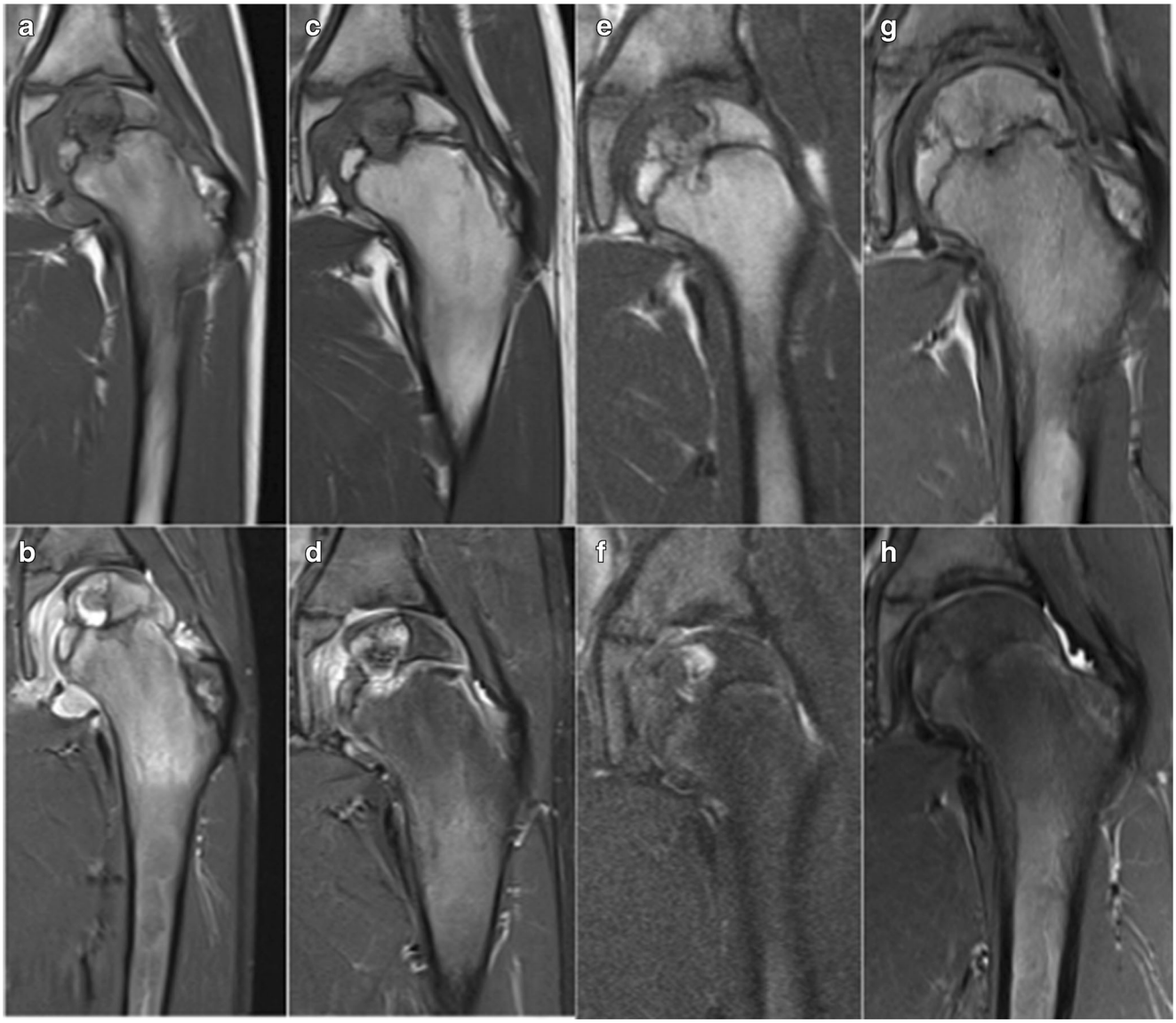

Fig. 3 **a** and **b** Pre-procedure MRI: Coronal T1-weighted and STIR sequences, respectively, of a focal lesion involving the epiphysis of the femoral head with surrounding bone marrow oedema and associated joint effusion. **c** and **d** Three months post-RFA MRI: Coronal T1-weighted and STIR sequences, respectively, demonstrate reduced perilesional oedema and a reduction in the joint effusion but some synovitis persisted around the liagmentum teres. **e** and **f** Six months post-RFA MRI: Coronal T1-weighted and STIR sequences, respectively, demonstrate marked infilling of the periphery of the old cavity with normal medullary fat. There was complete resolution of the perilesional oedema and effusion. **g** and **h** Twenty-four months post-RFA MRI: Coronal T1-weighted and STIR sequences, respectively, show further consolidation of the lesion, which was hardly identifiable. No evidence of oedema

necessitating the use of a multitined expandable electrode. This type of electrode produces a larger ablation zone than a single electrode, but potentially increases the risk of damage to nearby tissue. Based on successful cases [11, 12] and our experience, we prefer the use of single electrodes carefully placed under CT guidance to provide a tailored approach to cover the targeted area. For larger lesions, three needles can be placed simultaneously for a single 6-minute ablation and, following this, further needle placements can ensue to cover areas more cranial or caudal as required.

The complications of RFA have also been reported in a recent study by Lalam and coworkers [16]. A series of eight patients with relatively large lesions (range 1.2-5.0 cm, mean 2.7 cm) treated by RFA produced one case with a significant complication. The patient had a large lesion with a diameter up to 4.8 cm at the tibial plateau that breached the subchondral bone plate. Treatment of this lesion resulted in chondrolysis and articular surface collapse. The authors recognised that due to the size and site of the lesion, it was difficult to achieve positive outcomes by RFA or curettage.

Apart from long-term clinical outcomes from surgical outpatient follow-ups, our study provided serial MRI reviews for up to 3 years following RFA. Improvements in lesion characteristics identified on MRI postprocedure correlated directly with clinical and symptomatic recovery. All the patients were asymptomatic by 4 months post-RFA, and MRI follow-up demonstrated the first positive changes to be resolution of the joint effusion and reactive perilesional oedema. This change typically occurred within 6 months. During the follow-up period, we observed a common pattern of lesion healing. This involved a peripheral rim of high signal on T1 and a low signal on STIR indicating fatty infill. As serial MRI continued, there was progressive fatty infill leading to complete resolution of the cavity in a number of cases. No evidence of subchondral collapse was observed in our patients. In addition, serial MRI monitoring was also important in the early detection and timely treatment of disease recurrences. Imaging evidence for recurrence included a return of the perilesional oedema and joint effusion. These were the most reliable imaging signs and, along with the clinical features, led to repeat biopsy to confirm recurrent disease.

There were several limitations in this study. This was a single centre, descriptive, retrospective study without comparison to controls. In addition, we conducted the telephone interview using the MSTS score on a single occasion, and four patients were unable to be reached via telephone. In future evaluations, we would recommend the use of the MSTS score at each follow-up for a more comprehensive long-term functional assessment. The MSTS score should also be conducted on surgical patients to provide a comparative group against patients treated by RFA. Our study had a small sample size of 25 patients, but given the rarity of the condition, and recent introduction of this procedure, our study still consists of a relatively large sample size in regards to previous studies.

The authors used RF parameters in this study based on their experience in the treatment of other primary bone tumours and those recommended by the equipment manufacturers. It is unknown at this time what the optimum RFA time and temperature for the treatment of chondroblastoma might be. It is possible that reduced RFA time and temperature may be of value in treating lesions where there was risk to adjacent structures, but further research will be required to assess whether this is feasible. There are alternative treatment options that have been reported for the treatment of osteoid osteoma and osteoblastoma, which may be applicable to treat chondroblastoma. These include MR guided focused ultrasound ablation [17], cryoablation [18], microwave ablation [19], and laser ablation [20]. We are unable to comment on the use of these techniques for chondroblastoma management, and further research into the application of these techniques will help investigate their utility in the treatment of this condition. Finally, it is difficult to know whether the unsuccessful cases in this series reflect residual disease or recurrence. As no resection histology is available, we are unable to confirm complete tumour treatment and are reliant on clinical and imaging follow-up in these cases. It is, however, recognised that this is inevitable when percutaneous treatments such as RFA are being evaluated.

In conclusion, RFA is a safe and effective alternative to surgery in the management of chondroblastomas. Using the reported technique, we observed no immediate complications as a direct result of the procedure. RFA should, therefore, be considered as a first-line treatment for this rare tumour with outcomes similar in terms of recurrence to traditional surgical curettage. However, we believe that there is the potential for better functional outcomes in this technique than curettage, but further work on this aspect is required. It is important that a multidisciplinary approach in the management of this primary bone tumour is adopted when selecting patients for RFA. In addition, follow-up strategies should be in place for timely detection of recurrences.

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