Pediatr Radiol (2013) 43:814–819
DOI 10.1007/s00247-013-2636-y

ORIGINAL ARTICLE

Radiofrequency ablation in the treatment of osteoid osteoma: results and complications

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Received: 21 August 2012 / Revised: 27 November 2012 / Accepted: 4 December 2012 / Published online: 14 February 2013

Abstract
Background Percutaneous radiofrequency ablation (RFA) for treatment of osteoid osteoma is effective and avoids the potential complications of open surgical resection. This study evaluates the efficacy of RFA at a single tertiary-care pediatric hospital and highlights an important complication.
Materials and methods The medical records of 21 cases of RFA in 21 children between 2004 and 2010 were reviewed retrospectively for demographic data, lesion site, access point and technique for ablation, clinical outcome and complications.
Results Clinical follow-up was available for 17/21 children (81%) at an average of 17.0 months (range 0.5–86.1 months). No persistence or recurrence of pre-procedural pain was noted. Two children (9.5%) had a complication, including a burn to the local skin and muscle requiring local wound care, and a late subtrochanteric femur fracture treated successfully with open reduction internal fixation.
Conclusion RFA is a safe and effective alternative to surgical resection of the osteoid osteoma nidus. When accessing the proximal femur, the risk of late post-procedural fracture must be considered and discussed with the family. An understanding of biomechanical principles in the proximal femur might provide an effective strategy for limiting this risk.

Keywords Radiofrequency ablation · Osteoid osteoma · Complications · Fracture

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Introduction

Osteoid osteoma is a benign lesion of the bone found most commonly in the long bones of the lower extremity in children [1]. Classic symptoms include pain near the lesion, often increasing at night, that responds to non-steroidal anti-inflammatory medication. Although the lesion is benign, untreated lesions can lead to scoliosis, leg length discrepancy, and disuse osteopenia in addition to significant pain. Treatment is often sought early in the course of disease because the associated pain can affect daily activities.

Historically, surgical intervention consisted of en-block resection or open curettage of the nidus [2]. Image-guided drilling and, later, minimally invasive percutaneous radiofrequency ablation (RFA) techniques have been refined in an effort to avoid the morbidity of an extensive procedure.

Efficacy of these modern percutaneous techniques ranges from 83% to 92% and is comparable to reported open techniques [2–4].

A variety of self-limited soft-tissue complications from RFA procedures has been reported [4–9]. A review of the English literature did not yield any reported case of fracture, vascular injury or permanent nerve injury following RFA. The purpose of this study was to report the clinical outcomes and complications of radiofrequency ablation at a single tertiary-care pediatric hospital. The complication of a late subtrochanteric femur fracture through the ablation drill site is discussed in detail because it has not been reported in publications on modern RFA techniques.

Materials and methods

This retrospective case series was conducted at a single tertiary-care pediatric hospital. The study was approved by the hospital Institutional Review Board.

Patients

A retrospective review of the medical records was completed for patients treated at our institution for osteoid osteoma using radiofrequency ablation by the Interventional Radiology service between 2004 and 2010. We identified 21 lesions in 21 children. One additional child was excluded because the final pathology was consistent with chronic osteomyelitis. A pre-procedural biopsy was not performed in all children, as decided by the referring orthopedic surgeon when it was thought that the diagnosis was clear by history, exam and imaging studies.

Interventions

All ablation procedures reported in this study were performed by a single interventional radiologist (J.D.). Children were placed under general anesthesia and a limited localizing CT examination was performed (64 Sensation; Siemens, Erlangen, Germany). CT images with low-dose technique were used to guide placement of an 11-gauge insulated Osteo-Site bone biopsy needle (Cook Medical Systems, Bloomington, IN), onto to the cortex of the bone in line with the nidus of the osteoid osteoma. After removal of the trocar, a 1/8-in. hole was drilled with a hand-held drill through the nidus of the osteoid osteoma using the Osteo-Site needle as coaxial guide. The RFA needle, either an 11-gauge StarBurst access system or a 17-gauge UniBlate (both made by AngioDynamics, Latham, NY), was inserted through the Osteo-Site needle with 1 cm exposed active tip of the needle positioned within the nidus. The Osteo-Site needle was pulled back over the RFA needle to ensure no contact with the active tip. The RF generator was used to ablate the lesion at a target of 90° C for 5–6 min in the majority of children. Total time spent at the target temperature never exceeded 6 min, although ramp-up times to the target varied in some procedures because of occasional problems with the RF generator. The needles were removed and pressure was held on the site for 10 min. Hydrocodone analgesia was prescribed for 2–3 days as needed for pain. Children were instructed to avoid vigorous exercise for 3 weeks and contact sports for 6 weeks.

Outcome measures

Baseline information included age at presentation, date of procedure, location of the lesion, follow-up time and other diagnoses. Procedural information included the location of the cortical drill breach, number of drill holes utilized, and both time and temperature utilized for ablation. Clinical outcomes included the persistence or recurrence of symptoms and post-procedure complications. Initial radiographs and intra-procedural CT scans were reviewed to confirm the location of each lesion as well as the path of drill access used by the treating physician.

Results

Characteristics of the 21 children are summarized in Table 1. The mean age of our patient population was 11.4 years (range 2.5 – 28.6 years). There were 16 boys and 5 girls. The lesions occurred most commonly in the proximal femur (10/21, 47.6%), followed by the tibial shaft (3/21, 14.3%). The remaining lesions were seen in the femoral shaft (2/21, 9.5%), distal femur (2/21, 9.5%), distal tibia (2/21, 9.5%), distal humerus (1/21, 4.8%) and calcaneus (1/21, 4.8%). RFA treatments lasted an average of 7.5 min, though only 5–6 min was spent at the target temperature. Although the average target was 90.7° C, all but three children were treated at a target of 90° C. Three children (patients 6, 19, and 20; Table 1) required two drill holes because of the shape of their lesion. Of note, one RFA patient had previously undergone an open biopsy of osteoid osteoma at the same location to confirm the diagnosis.

Clinical follow-up with interventional radiology was available in 17 of 21 children (81%) with an average follow up of 17.0 months (range 0.5–86.1 months) through review of patient records (14/17) or via telephone (3/17). Of the children available for follow-up, one child reported mild post-procedural discomfort for several days that resolved without further intervention. All children with follow-up reported a complete resolution of pain symptoms after their primary procedure and no children experienced a recurrence.

Table 1 Patient and procedure data

Patient	Age (years)	Gender	Bone	Lesion location	Cortical breach	Time (min)	Temperature (°C)
1	10.6	M	R proximal femur	Posteromedial neck	Anterolateral	7.2	N/A
2	10.8	M	R proximal femur	Posteromedial neck	Anterolateral	5.0	90
3	7.7	F	R proximal femur	Posteromedial diaphysis, subtroch	Lateral	5.0	90
4	11.4	F	R proximal femur	Medial diaphysis, subtroch	N/A	8.0	90
5	11.9	M	R proximal femur	Lesser trochanter	Anterolateral	6×2	N/A
6[a]	12.5	M	R proximal femur	Proximal diaphysis, medullary	1: Lateral	1: 5.0	1: 97
					2: Lateral	2: 5.0	2: 97
7	2.5	M	L proximal femur	Posteromedial diaphysis	Lateral	6.0	100
8	5.7	M	L proximal femur	Anteromedial diaphysis, subtroch	N/A	6.0	90
9	12.2	M	L proximal femur	Greater trochanter apophysis	Lateral	6.0	90
10	7.3	M	L proximal femur	Anterior neck	1: Anterior	1: 7.0	1: 90[b]
					2: Anterior	2: 6.0	2: 90
11	14.9	M	R mid-femur	Anteromedial diaphysis	Lateral	6.0	90
12[c]	7.0	M	L mid-femur	Lateral diaphysis	Lateral	4.0	90
13	8.2	M	L distal femur	Lateral metaphysis	Lateral	8.2	90
14	9.9	M	L distal femur	Medial metaphysis	Anterior	5.0×2	N/A
15	6.4	F	R mid-tibia	Posterior diaphysis	Anteromedial	6.0	90
16	12.5	F	L mid-tibia	Medial diaphysis	Medial	5.0	90
17	13.4	M	L mid-tibia	Diaphyseal, medullary	Anteromedial	5.0	90
18	16.6	M	R distal tibia	Posterolateral diaphysis	Anteromedial	5.0	90
19	15.8	M	L distal tibia	Posterior diaphysis	Anterior	6.0	90
20	28.6	M	L calcaneus	Subchondral, posterior facet	1: Lateral	1: 10.0	1: 90
					2: Lateral	2: 6.0	2: 90
21	13.0	F	R distal humerus	Posterior diaphysis	Posterior	6.0	85

[a] Complicated by subtrochanteric fracture 9 weeks after procedure

[b] Last minute of ablation performed at 100° C

[c] Complicated by skin/muscle burn during procedure

Two complications occurred in our patient population (2/21, 9.5%). A 12-year-old boy (patient 6) with an intramedullary osteoid osteoma in the proximal femoral diaphysis was treated with RFA through two lateral cortical breaches 1.5 cm apart in the proximal femur. Both sites were independently ablated for 5 min at 97° C. The decision to treat through two cortical breaches was made secondary to the elongated shape of the endosteal lesion. Histological review of tissue obtained during the procedure confirmed the diagnosis and tissue cultures were negative for infection. Nine weeks after his treatment the boy fell while wrestling with a classmate with a resulting subtrochanteric fracture through the inferior drill hole (Fig. 1). He was taken to the operating room for open reduction and compression plating of the proximal femur. This treatment was successful, although the 4.5 months to complete healing was longer than expected (Fig. 2).

The second complication occurred in a child with osteoid osteoma of the femur who had undergone open biopsy of the lesion 17 months prior to RFA. This child (patient 12) received 4 min of RFA treatment at 90° C with resulting burn of the vastus lateralis muscle (confirmed by MRI) and a 10-mm diameter second-degree burn to the skin adjacent to the puncture site. Plastic surgeons treated the wound with wet-to-dry dressings and Apligraf (Novartis, Basel, Switzerland). The wound healed uneventfully.

Discussion

With the development of better imaging modalities, precise lesion localization and image-guided minimally invasive percutaneous ablation through a drill-hole made in the bone cortex has become increasingly common [2, 5, 10–14]. Modern ablation techniques have been shown to be equivalent to surgery in terms of treatment efficacy of non-spinal osteoid osteomas [6, 15], with an efficacy of 91% following primary procedures at 2 years' follow-up in one large retrospective study of 271

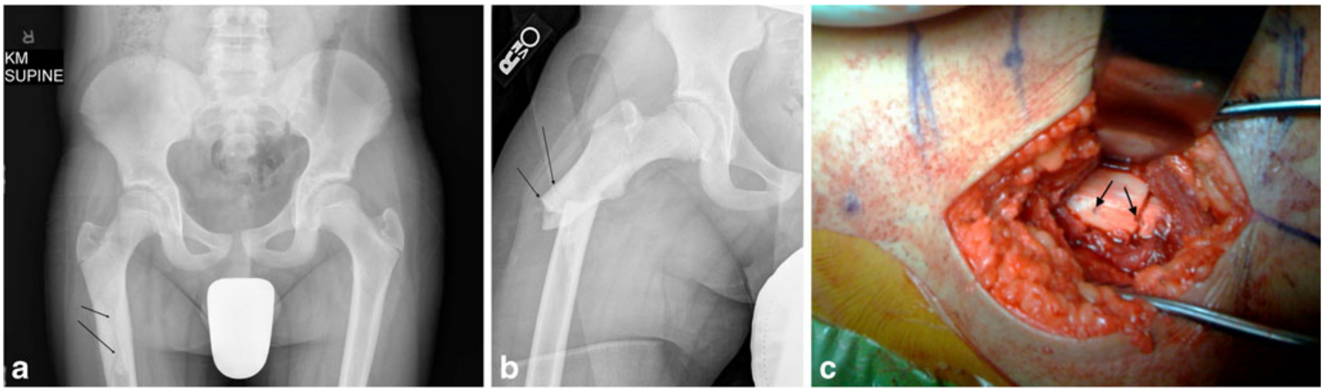

Fig. 1 Images in a 12-year-old boy who sustained a subtrochanteric femur fracture 9 weeks post ablation. **a** Pre-ablation AP pelvis radiograph demonstrates intramedullary subtrochanteric osteoid osteoma lesion (*arrows*). Diagnosis was confirmed by pathological specimen. **b** Subtrochanteric femur fracture at 9 weeks post ablation. Superior and inferior drill holes are visible, with the fracture through the inferior defect (*arrows*). **c** Intraoperative photograph demonstrates the appearance of two lateral drill holes 9 weeks after RFA procedure (*arrows*). The fracture is seen traversing the inferior hole (*right*)

patients [15]. Although the patient numbers in our review are significantly smaller, our experience using a similar RFA protocol is comparable to results published in the literature.

CT-guided radiofrequency ablation has gained support among clinicians because of its high efficacy and several other perceived advantages over surgery: lower cost, lower complication rates, short or no hospital stays and a less-traumatic access for deep anatomical locations such as the proximal femur and pelvis [1, 15]. Unfortunately, the incidence and extent of complications from percutaneous drilling and ablation, as well as the clinical results of treatment, have not been investigated in peer-reviewed journals. Some of the published complications include transient sympathetic dystrophy [15], superficial skin burns [3, 5, 16], cellulitis [15], osteocutaneous fistula requiring surgical debridement [12], a self-limiting palsy of the extensor hallucis longus muscle [4], and self-limiting numbness of the thigh surrounding an ablation tract [7]. An older study on CT-guided drilling without RFA reported a femoral shaft fracture at 4 weeks, though this procedure involved drilling the nidus with a 7-mm bit [8]. However, a review of only those papers in the English literature that utilized RFA techniques did not yield any documented case of vascular injury, permanent nerve injury, or fracture.

An understanding of fracture risk associated with this procedure requires an understanding of the material properties of bone and biomechanics of the skeleton under

Fig. 2 Successful healing in the boy from Fig. 1 can be seen on AP (**a**) and lateral (**b**) radiographs 14 months after open reduction internal fixation

physiological load. Bone is an anisotropic material that resists compressive forces better than tensile (distraction) forces. When bone that is loaded in tension becomes weakened by osteoporosis, stress fracture or surgical procedures it is more prone to fracture than similar bone loaded in compression. This phenomenon is particularly important in the proximal femur as a result of its anatomy and biomechanics. The offset of the femoral shaft from the femoral head by way of its neck creates an anatomical axis in approximately 7° of valgus off the weight-bearing mechanical axis, which runs from the center of the femoral head to the center of the knee (Fig. 3). As a result, the proximal femur is an eccentrically loaded segment of bone, with the head, inferior neck and medial cortex in the proximal shaft all experiencing primarily compressive loads, while the superior neck and lateral cortex experience primarily tensile loads [9, 17]. This is particularly true in the region of the subtrochanteric proximal femur, classically defined as the five centimeters of bone distal to the lesser trochanter, where the bone is at its furthest deviation from the weight-bearing axis.

Because of bone anisotropy, surgical drill holes would ideally be placed through a region under compression, because this would leave the bone less vulnerable to post-procedural fracture. Unfortunately, osteoid osteoma lesions are commonly located in the proximal femur and an approach through compressively loaded bone on the medial side with a drill is not typically performed because of the risks to overlying neurovascular structures and soft-tissue anatomy. Therefore, these lesions are more safely approached from the lateral side. When drilling through the lateral cortex of the proximal femur, the hole in the bone is created on the tension side, leaving it weakened and more susceptible to fracture. This is especially true in the subtrochanteric region of the femur. In addition, radiofrequency ablation not only heats and causes necrosis of cellular material of the osteoid osteoma but also of the surrounding bone for a diameter of approximately 1 cm surrounding the needle. The necrotic bone in this high-stress region becomes unable to repair the microscopic damage of daily activity, potentially elevating the risk for fracture even further.

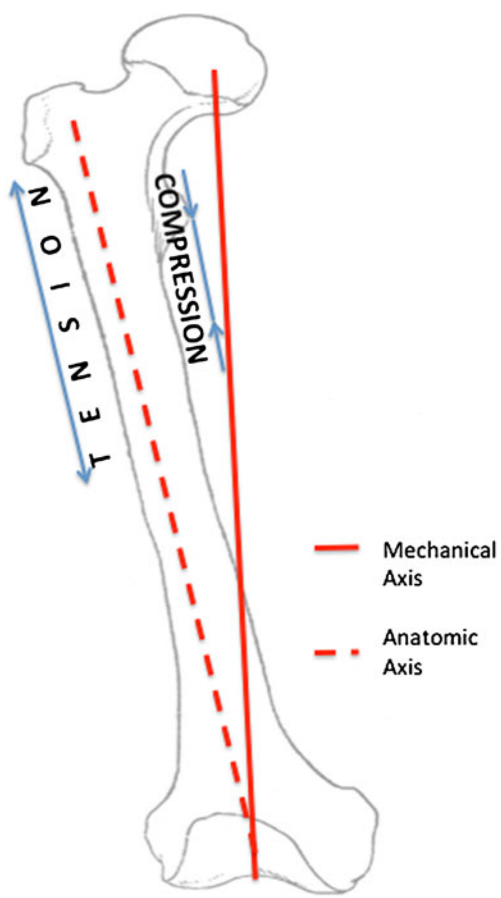

Fig. 3 Diagram of mechanical and anatomical axes of the femur with resulting tensile (lateral) and compressive (medial) zones proximally

The risk of fracture of the proximal femur following the placement of lateral metal implants is well known in orthopedic trauma. Subtrochanteric fractures as a complication of internal fixation of femoral neck fractures with screws have been addressed in the literature. It has been shown that lateral screw placement below the level of lesser trochanter results in stress risers that can lead to bone failure [18–21]. Kloen et al. [20] made specific recommendations in this regard, including avoidance of screw placement below the level of the lesser trochanter because of the high amount of tensile stress in this area. Our femoral fracture complication occurred through a still-patent drill hole 9 weeks after treatment. Therefore, it seems reasonable to extrapolate recommendations for lateral drill-hole placement in the proximal femur from the trauma literature to RFA treatment of osteoid osteoma.

There are some limitations to the conclusions that can be drawn from this study. With regard to clinical outcome, the small sample size, retrospective nature of our data collection and lack of a surgical comparison cohort prevent us from making definitive statements on the efficacy of RFA for treatment of osteoid osteoma. Finally, the pathological fracture seen in our case series was unlikely to be a result of the approach location alone. Other procedural factors (e.g., use of a 1/8-in. drill) and patient factors (e.g., older age—13 years with an average of 11.4 in this series), size (68 kg) and vigorous activity at the time of injury were likely to have contributed. The stresses placed on the femur by this boy were sufficient to fracture with the weakened bone at the RFA site even 9 weeks after his procedure. All patients are told to limit physical activity for 6 weeks even though they are symptom-free within a couple days of the procedure. Still, our results demonstrate a procedure with a relatively low complication rate and excellent success at relieving symptoms. The procedure is safe and spares the morbidity of open surgical procedures.

Conclusion

One major concern of en bloc surgical nidus excision is weakening of the bone and subsequent fracture risk. In theory, a percutaneous method of nidus ablation through a small drill hole would lower this risk and have less morbidity, therefore increasing the margin of safety for children undergoing this procedure. We have found that RFA is an efficacious modality of osteoid osteoma treatment; however, the risk of fracture is not entirely eliminated by this minimally invasive procedure. On account of the material properties of bone, the biomechanics of the proximal femur and the risks of stress risers, the lateral proximal femur should be approached with caution when treating osteoid osteoma lesions with RFA. One should consider avoiding the lateral tensile side in favor of a more anterior approach to the bone whenever feasible. If the lateral tensile side cannot be avoided, the lateral cortical breech should be above the level of the lesser trochanter and limited to a single drill hole. Restrictions on jumping, running and torsional activities in the post-procedural setting are also strongly recommended, although we are unable to make a definitive statement on the proper duration and recognize that compliance is difficult in this young, active patient population. We believe our experience demonstrates the efficacy of RFA in the treatment of osteoid osteoma while raising awareness of fracture risk in the proximal femur.

Acknowledgement We would like to thank Brittany Patrick, MPH, for her help and contributions to this project.

Conflicts of interest None

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