Cardiovasc Intervent Radiol (2018) 41:1384–1390
https://doi.org/10.1007/s00270-018-1947-7

Percutaneous Radiofrequency Ablation for the Treatment of Osteoid Osteoma in Children and Adults: A Comparative Analysis in 92 Patients

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Received: 17 January 2018 / Accepted: 23 March 2018 / Published online: 12 April 2018

Abstract
Purpose To compare technical success, complications, and long-term clinical success following radiofrequency ablation of osteoid osteomas in pediatric and adult patients.
Materials and Methods Ninety-two patients underwent percutaneous computed tomography-guided radiofrequency ablation for osteoid osteomas including 54 pediatric (mean age 12.9 years) and 38 adult (mean age 24.1 years) patients. Presenting indication, osteoma location, ablation method, technical success, complications, visual analog score, radiographic follow-up, clinical success, reintervention rate, and total follow-up were reported. Technical success was defined as placement of the probe in the radiolucent nidus with ablation. Clinical success was defined as resolution of symptoms.
Results Ablation indications included: pain localized to the lesion, night pain, and an osteoma on imaging in all patients. Majority of osteoid osteomas were localized to the femur (pediatric [n = 22, 40.7%]; adult [n = 12, 34.2%]) and tibia (pediatric [n = 21, 38.9%]; adult [n = 10, 26.3%]). Mean lesion size was 9.6 mm in pediatric patients and 9.0 mm in adults. Technical success was achieved in all pediatric patients (100%) and 97.4% of adults. Two complications occurred. Primary clinical success was achieved in 49 (90.7%) pediatric and 35 (92.1%) adult patients. Five (9.3%) pediatric and 3 (7.9%) adult patients sought reintervention for residual symptoms, and all had secondary clinical success. Mean total follow-up was 95.2 ± 58.7 months in pediatric and 90.0 ± 61.6 months in adult patients. No differences in outcomes were identified between pediatric and adult patients.
Conclusion Radiofrequency ablation of osteoid osteomas is safe with excellent technical and clinical success rates in pediatric and adult patients.

Keywords Osteoid osteoma · Radiofrequency · Ablation

Introduction

Osteoid osteomas are benign, painful osteoblastic tumors that arise most commonly in young men [1]. Severe pain typically appears at night at the site of the lesion; however, this may be constant at any time during the day [1–3]. Radiographically, osteoid osteomas appear as a small (typically < 20 mm) cortically based radiolucent nidus with surrounding dense sclerosis although less commonly may be intra-medullary [1–3]. The standard of care for the treatment of osteoid osteomas is image-guided ablation. The technique was first described in 1992 by Rosenthal, and since, numerous prospective and retrospective studies have demonstrated its superiority to other invasive methods [4, 5]. Surgical excision is an alternative with perhaps greater success rates, but is less commonly performed given its invasive nature [4–6].

While there have been numerous prospective and retrospective studies on percutaneous ablation for osteoid

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osteomas, there has yet to be a comparative analysis between pediatric and adult patients in a single study [2, 4–21]. Outcomes for adults and youth are favorable, though questions remain regarding differences between these two cohorts.

This study compares the technical success, complications, and primary and secondary clinical successes in pediatric and adult patients following radiofrequency ablation of osteoid osteomas.

Materials and Methods

Patient Selection

This study was conducted with institutional review board approval and complied with the Health Insurance Portability and Accountability Act. Informed consent was not required for this retrospective study. A retrospective search of the Electronic Medical Record Search (EMERSE; Ann Arbor, MI) database was performed from October 2002 to July 2017 (177 months) using the terms "osteoid osteoma" and "ablation." This yielded 177 patients.

Inclusion/Exclusion Criteria

All patients suspected to have osteoid osteomas were considered for inclusion ($N = 177$). Medical records were reviewed to reveal 92 (52.0%) patients who underwent percutaneous radiofrequency ablation of an osteoid osteoma, and were therefore included in the study cohort. Patients who underwent cryoablation of an osteoid osteoma ($n = 3$) were not included given small sample size.

Patient Demographics

Patient characteristics are given in Table 1. Of the 92 patients, there were 54 (58.7%) pediatric and 38 (41.3%) adult patients. There were 28 (51.9%) males and 26 (48.1%) female pediatric patients with a mean age of 12.9 ± 3.3 (range 4–17 years). As for the adult cohort, there were 31 (81.6%) males and 7 (18.4%) females with a mean age of 24.1 ± 6.5 (range 18–42 years). There were significantly more males than females in the adult group ($P = 0.004$). Nearly all patients presented with chronic pain at the lesion site, and 43 (75.4%) pediatric and 34 (89.5%) adult patients complained of night pain ($P = 0.251$). Oral analgesics were effective in 94.4% of pediatric and 92.1% of adult patients ($P = 0.688$).

Imaging

Advanced imaging after initial evaluation with plain film radiograph was completed via computed tomography, magnetic resonance imaging, or bone scintigraphy. Plain films were acquired prior to ablation in all (100%) patients. Additional imaging modalities, including computed tomography (pediatric [$n = 49$, 90.7%]; adult [$n = 34$, 89.5%]), magnetic resonance imaging (pediatric [$n = 15$, 27.8%]; adult [$n = 18$, 47.4%]), and bone scans (pediatric [$n = 2$, 3.7%]; adult [$n = 1$, 2.6%])were not statistically different between pediatric and adult patients ($P = 0.711$).

Medical records and imaging were reviewed for size of the radiolucent nidus, location, and whether the lesion was intra-cortical or trabecular and intra- or extra-articular. Follow-up imaging modality was recorded and reviewed to determine whether the ablation was complete. Time to first follow-up imaging was recorded. If a patient underwent reintervention during the study period, repeat imaging was reviewed for evidence of new or recurrent lesion.

Pain

Visual analog scale (VAS) for numeric pain scores (0–10) were recorded at presentation and initial follow-up. Whether patients responded to home analgesics was also recorded. Visual analog scale pain score at reintervention was also recorded.

Technique

For all patients, general anesthesia was utilized in addition to local lidocaine at the biopsy and ablation sites. An 11-gauge bone biopsy needle was advanced into the osteoid osteoma under image guidance. In cases with dense perilesional sclerosis, the tumor was reached through a drill advanced over an appropriate guidewire. Then, a 14-gauge electrode was introduced into the lesion nidus through a coaxial system. The electrode was connected to the radiofrequency generator, and the tip temperature was increased to 90 °C. One cycle of radiofrequency ablation was defined as ablation at 90 °C for a minimum of 5 min followed by passive cooling to approximately 40 °C.

Number of ablation cycles during the same procedure, overall ablation time (min), number of times the needle was repositioned, and biopsy results were also recorded. The size of the ablation area was chosen to encompass the radiolucent nidus and a 5-mm margin. Thermocouples and spinal cord protection techniques were utilized for ablations around the spinal cord [18, 20, 22].

Table 1 Patient characteristics

Patient characteristics	All cases	$n = 92$	Pediatric	$n = 54$	Adult	$n = 38$	P value
Sex							
Male	59	64.1%	28	51.9%	31	81.6%	0.004
Female	33	35.9%	26	48.1%	7	18.4%	
Age (years)							
Mean, SD	17.5	7.4	12.9	3.3	24.1	6.5	
Range	4	42	4	17	18	42	
Presenting symptoms							
Night pain	77	81.1%	43	75.4%	34	89.5%	0.251
Pain relief with NSAID	86	93.5%	51	94.4%	35	92.1%	0.688
Lesion size (mm)							
Mean, SD	9.4	5.2	9.6	5.8	9.0	4.3	0.700
Range	3	32	3	32	3	64	
Lesion location							
Femur	35	38.0%	22	40.7%	13	34.2%	0.147
Tibia	31	33.7%	21	38.9%	10	26.3%	
Humerus	7	7.6%	5	9.3%	2	5.3%	
Foot	7	7.6%	3	5.6%	4	10.5%	
Fibula	5	5.4%	1	1.9%	4	10.5%	
Acetabulum	3	3.3%	0	0.0%	3	7.9%	
Spine	1	1.1%	0	0.0%	1	2.6%	
Scapula	1	1.1%	1	1.9%	0	0.0%	
Ulna	1	1.1%	1	1.9%	0	0.0%	
Radius	1	1.1%	0	0.0%	1	2.6%	
Cortical	89	96.7%	51	94.4%	38	100.0%	0.412
Medullary	3	3.3%	3	5.6%	0	0.0%	
Extra-articular	89	96.8%	53	98.1%	35	94.6%	0.560
Intra-articular	3	3.2%	1	1.9%	2	5.4%	
Imaging prior to ablation							
Plain film	92	100.0%	54	100.0%	38	100.0%	0.711
CT	83	90.2%	49	90.7%	34	89.5%	
MRI	33	35.9%	15	27.8%	18	47.4%	
Bone scan	3	3.3%	2	3.7%	1	2.6%	

Variables and Outcomes

Technical success, reintervention rate, primary and secondary clinical successes, and total follow-up time (days) were recorded. Technical success was defined as successful placement of the ablation probe tip into the radiolucent nidus followed by ablation with intra-procedural imaging showing adequate coverage of the nidus by the ablation zone. Primary clinical success was defined as visual analog scale of 1 or less after a single ablation. Secondary clinical success was defined as visual analog scale of 1 or less following repeated ablations. Reintervention was further delineated between disease recurrence and incomplete treatment. Disease recurrence was defined as significant increase in visual analog scale after complete ablation or as determined by imaging. Incomplete treatment was defined as a significant increase in visual analog scale and evidence of incomplete ablation on follow-up imaging.

Statistical Analysis

Mean, median, standard deviation, standard error, and interquartile ranges were calculated using spreadsheet software (Excel, Microsoft; Redmond, WA). P values were calculated using the Student's t test (or Mann–Whitney) for continuous variables, and Chi-square test (or Fischer's exact test) for categorical variables. P values < 0.05 were considered statistically significant. Kaplan–Meier curve and box plots were generated using SPSS 20.0 software (IBM; North Castle, NY).

Results

Imaging

Pre-procedural imaging is given in Table 1. Pre-procedural imaging was acquired in all patients with computed tomography (pediatric [n = 49, 90.7%]; adult [n = 34, 89.5%]), magnetic resonance imaging (pediatric [n = 15, 27.8%]; adult [n = 18, 47.4%]), and nuclear imaging (pediatric [n = 2, 3.7%]; adult [n = 1, 2.6%]). Some patients had multiple imaging modalities preoperatively. There were no statistical differences in the utilization of imaging modalities between pediatric and adult patients in the pre-procedural setting (P = 0.711).

Post-ablation imaging was acquired in 36 (66.7%) pediatric and 25 (65.8%) adult patients (P = 0.466). Of the pediatric patients, 31 (57.4%) had follow-up plain film radiography and 5 (9.3%) pediatric patients had follow-up computed tomography. For adult follow-up imaging, 22 (57.9%) had plain film radiography, 1 (2.6%) underwent computed tomography, and 2 (5.3%) underwent magnetic resonance imaging.

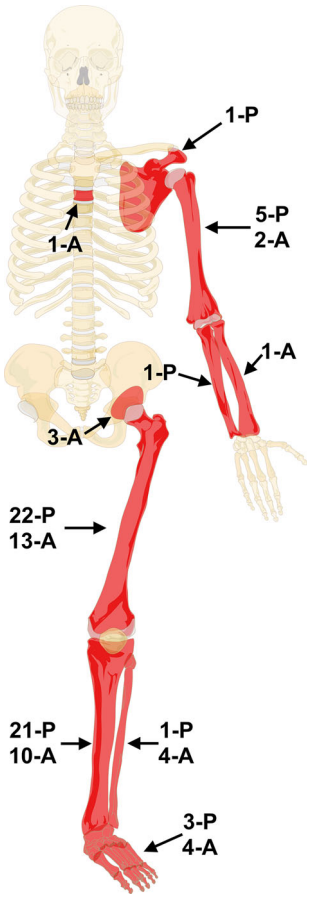

Fig. 1 Distribution of pediatric (P) and adult (A) osteoid osteomas. Lesion sites include: femur, tibia, fibula, foot, humerus, radius, ulna, acetabulum, scapula, and T4 vertebrae. *Note* diagram does not reflect sidedness

Lesion Characteristics

Lesion metrics and locations are presented in Table 1 and Fig. 1. Mean lesion size for pediatric and adult patients was 9.6 ± 5.8 mm (range 3–32 mm) and 9.0 ± 4.3 mm (range 3–64 mm), respectively. No statistical difference in lesion size was noted between pediatric and adult patients (P = 0.700). Osteoid osteomas were localized to the femur (pediatric [n = 22, 40.7%]; adult [n = 13, 34.2%]), tibia (pediatric [n = 21, 38.9%]; adult [n = 10, 26.3%]), humerus (pediatric [n = 5, 9.3%]; adult [n = 2, 5.3%]), foot (pediatric [n = 3; 5.6%]; adult [n = 4, 10.5%]), fibula (pediatric [n = 1, 1.9%]; adult [n = 4, 10.5%]), acetabulum (adult [n = 3, 7.9%]), spine (adult [n = 1, 2.6%]), scapula (pediatric [n = 1, 1.9%]), radius (adult [n = 1, 2.6%]), and ulna (pediatric [n = 1, 1.9%]). There was no statistical significance in the trend of lesion locations between pediatric and adult patients; however, there was a trend toward a broader distribution of lesions in the adult cases (P = 0.147). Nearly all lesions were intra-cortical, aside from 3 pediatric patients with intra-medullary osteoid osteomas, two located in the proximal femur and one in the mid-femur. Three osteoid osteomas were intra-articular, all located at the cortex of the femoral head within the hip joint.

Ablation Techniques

Ablation techniques are given in Table 2. The mean number of ablation cycles for pediatric patients was 1.2 ± 0.5, and 1.1 ± 0.3 for adults. Mean total ablation time for pediatric patients was 6.8 ± 3.3, and 6.5 ± 1.6 min for adults. The number of needle positions was similar between pediatric and adult patients, with 1.2 ± 0.53 and 1.1 ± 0.23 mean positions per case, respectively.

Biopsy

Biopsy results are given in Table 3. Forty-eight (84.2%) pediatric and 36 (94.7%) adult patients underwent pre-procedural biopsy. Of those biopsy specimens, 28 (58.3%) pediatric and 15 (41.7%) adult were confirmed cases of osteoid osteomas, while 20 (41.7%) pediatric and 21 (58.3%) adult cases were non-diagnostic or negative for osteoid osteoma. Reintervention rates for patients with pathologic evidence of osteoid osteoma and non-diagnostic or negative samples were 6.7 and 14.3%, respectively (P = 0.304).

Table 2 Percutaneous osteoid osteoma radiofrequency ablation techniques

Radiofrequency ablation techniques	All cases	$n = 92$	Pediatric	$n = 54$	Adult	$n = 38$	P value
Number of ablation cycles (mean, SD)	1.1	0.5	1.2	0.5	1.1	0.3	0.239
Ablation time per cycle (min) (mean, SD)	5.7	1.1	5.6	1.4	6	0	0.075
Total ablation time (min) (mean, SD)	6.7	2.7	6.8	3.3	6.5	1.6	0.096
Number of needle positioning (mean, SD)	1.1	0.43	1.2	0.53	1.1	0.23	0.312

Table 3 Percutaneous osteoid osteoma ablation follow-up and outcomes

Outcomes	All cases	$n = 92$	Pediatric	$n = 54$	Adult	$n = 38$	P value
Imaging post-ablation	61	66.3%	36	66.7%	25	65.8%	0.466
X-ray	53	57.6%	31	57.4%	22	57.9%	
CT	6	6.5%	5	9.3%	1	2.6%	
MRI	2	2.2%	0	0.0%	2	5.3%	
Biopsy results							
Number with biopsy	84	91.3%	48	84.2%	36	94.7%	0.192
Osteoid osteoma	43	51.2%	28	58.3%	15	41.7%	0.130
Non-diagnostic	41	48.8%	20	41.7%	21	58.3%	
Days to follow-up imaging (mean, SD)	24.6	17.8	23.5	17.5	26.1	18.4	0.639
Total follow-up in months (mean, SD)	93.1	59.6	95.2	58.7	90.0	61.6	0.815
Technical success	91	98.9%	54	100.0%	37	97.4%	0.218
Reinterventions							
Total	8	8.7%	5	9.3%	3	7.9%	0.668
Incomplete treatment	2	2.2%	1	1.9%	1	2.6%	
Recurrence	6	6.5%	4	7.4%	2	5.3%	0.698
Months to reintervention (mean, SD)	35.5	55.6	43.6	71.0	21.9	17.4	0.719
VAS pain score (median, IQR)							
Pre-procedure	8	8–9	8	8–9	6	6–8	0.142
Post-procedure	0	0–1	0	0–1	0	0–1	
Complete resolution of symptoms at initial follow-up	71	77.2%	41	75.9%	30	78.9%	0.805
Primary clinical success	84	91.3%	49	90.7%	35	92.1%	0.880
Secondary clinical success	8	100.0%	5	100.0%	3	100.0%	

Outcomes

Outcomes are presented in Table 3 and Fig. 2. Overall, there were no significant differences between pediatric and adult outcomes. Mean time between ablation and first follow-up imaging was 23.5 ± 17.5 days for pediatric patients and 26.1 ± 18.4 days for adult patients. Total mean follow-up was 95.2 ± 58.7 months for pediatric and 90.0 ± 61.6 months for adult patients. Overall technical success was achieved in 91 cases (98.9%), 54 (100%) pediatric, and 37 (97.4%) adults. The one technical failure in an adult patient was due to ablation probe misplacement.

In total, there were 8 reinterventions during the study period: 5 (9.3%) pediatric and 3 (7.9%) adult patients ($P = 0.668$). All reinterventions were performed for pain recurrence. Of the reinterventions, 2 (1 pediatric, 1 adult) were due to incomplete treatment and 6 (4 pediatric, 2 adult) were classified as recurrent osteoid osteoma. Median (interquartile range) VAS pain score pre- and post-ablation was 8 [8, 9] and 0 [0–1] for pediatric cases and 6 [6–8] and 0 [0–1] for adult cases, respectively. 91.3% of patients had primary clinical success at initial follow-up, with similar rates in pediatric (90.7%) and adult (92.1%) patients ($P = 0.880$). The majority of pediatric (75.9%) and adult (78.9%) patients experienced complete resolution of symptoms at initial follow-up. Primary clinical success was not statistically different at any point between groups with an overall mean of 31.9 ± 53.1 months (Fig. 2).

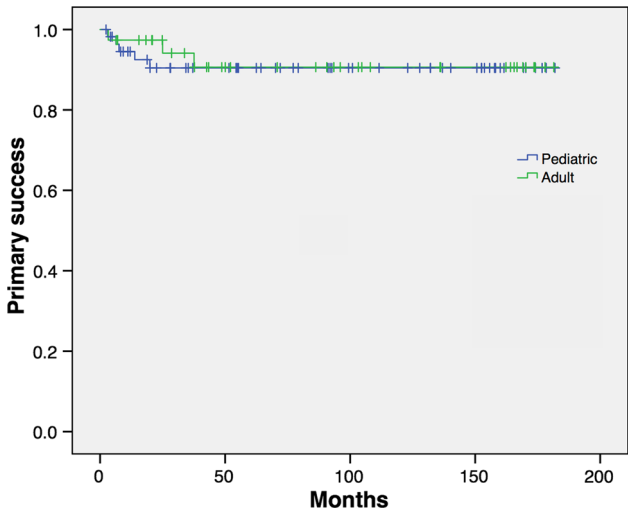

Fig. 2 Primary success rate following initial percutaneous ablation of osteoid osteoma. No significant difference was observed at any point at a 95% confidence interval

Additionally, there was a trend toward earlier reintervention in pediatric patients; however, this did not reach statistical significance at a 95% confidence interval (Fig. 2). Secondary success was achieved in all 8 patients requiring reintervention (5 pediatric and 3 adult cases).

Complications

There were two Society of Interventional Radiology Class D complications, including a man who sustained a thigh abscess following radiofrequency ablation of a proximal femoral osteoid osteoma 3 days following the procedure [23]. He fully recovered after incision and drainage followed by a course of antibiotics. Additionally, one patient had rapid onset of flash pulmonary edema following the procedure. The patient survived following 13 days of ventilation and intensive care.

Discussion

Our results confirm that percutaneous ablation is the treatment of choice for osteoid osteomas, and suggests that few differences exist between pediatric and adult patients with respect to clinical presentation, follow-up, and outcomes. Our overall technical and primary clinical success was 98.9 and 91.3%, respectively. These rates are in line with prior publications including a recent review of 1772 patients [2, 5–14, 16–21, 24]. Additionally, our rates of complete pain relief following first radiofrequency ablation (77.2%) are also consistent with prior studies [8, 11]. Long-term outcomes are also favorable with sustained primary clinical success above 90% after 18 months (Fig. 2) and 100% secondary clinical success (Table 3). There was a trend toward earlier reintervention in children; however, this observation did not reach statistical significance at a 95% confidence interval.

Of the 8 (8.7%) patients (5 pediatric, 3 adult) who required reintervention for recurrence of symptoms, the majority (6/8) were recurrent osteoid osteoma rather than incomplete treatment. This suggests that most recurrences were not due to incomplete treatment and that the procedure was likely technically satisfactory in these cases. Moreover, this supports the need for at least one follow-up computed tomography or magnetic resonance imaging at 12 months to monitor for recurrence as suggested by some authors [8].

While nearly all patients (91.6%) underwent percutaneous biopsy prior to ablation, only 51.7% of samples were diagnostic for osteoid osteoma consistent with prior publications [8, 11, 12]. While there were relatively few reinterventions, there was no significant difference between reintervention rates of patients without and with pathologic evidence of osteoid osteoma. As such, it has been argued that biopsy should only be mandated in cases where radiographic and clinical evidences are not diagnostic for osteoid osteoma.

Interestingly, there were marginally higher rates for the use of computed tomography in children (9.3%) compared to adults (2.6%) for advanced diagnostic follow-up imaging. Given the susceptibility of this cohort to long-term radiation exposure, magnetic resonance imaging may be underutilized. It is critical to educate patients and their caretakers about the risks and benefits of computed tomography in the evaluation of bone lesions that are clinically suspicious for osteoid osteoma.

Though we aimed to adhere to proposed osteoid osteoma reporting guidelines, there were several limitations to this study including its retrospective nature [8]. Additionally, different cohorts of operators generally performed adult ablation procedures versus pediatric ablation procedures, so variability in imaging and ablation parameters may be in part related to individual operator preferences. Also, pre- and postoperative pain scores in younger pediatric patients were sometimes reflective of parental assessment of pain score due to age.

Conclusion

Radiofrequency ablation of osteoid osteomas is safe and viable with excellent technical and clinical success rates regardless of age.

Authors' contribution All authors have read and contributed to this manuscript.

Compliance with ethical standards

Conflict of interest The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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