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The efficacy of computed tomography-guided percutaneous microwave ablation in patients with osteoid osteoma according to nidus location in long bones: A single-centre initial experience

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Abstract

This study aims to assess the efficacy of microwave ablation (MWA) treatment in painful extra-articular osteoid osteoma (OO) in long bones in a consecutive series of patients and to compare the technical and clinical success in terms of pain scores according to their location. A total of 23 patients who were diagnosed with OO in long bones and treated with MWA between January 1, 2016, and June 1, 2020 were enrolled in this study. Medical data and images were reviewed for age, gender, size of the nidus and duration of pain. Patients were then categorized into three groups according to the location of nidus (pertrochanteric, metaphyseal or diaphyseal). Operation length and technical and clinical success rates were compared. Technical success was achieved in 100% of patients. Primary clinical success following MWA was 82.6%. The most common location was the pertrochanteric region (34.8%). In comparing the pain scores with the locations of the lesions, no statistically significant difference was found between the first-day ($p = 0.504$) and first-week ($p = 0.648$). However, significant difference was present between the first month ($p = 0.016$), third month ($p < 0.001$) and sixth month ($p = 0.001$). The statistically significant differences between the sites were due to the difference between the pertrochanteric and diaphyseal lesions. CT-guided percutaneous MWA is safe and effective in the treatment of OO located in long bones without any recurrence. However, management of pertrochanteric OOs requires specific expertise and follow up. Further studies are expected in the future to assess the long-term efficacy and safety of MWA for the treatment of OO, especially for cases in pertrochanteric locations of the femur, which have an increased risk of local recurrence.

Keywords: microwave ablation, osteoid osteoma, bone tumor, clinical efficacy

1. Introduction

Osteoid osteoma (OO) is a benign inflammatory bone tumour of unknown etiology that accounts for 2–3% of all primary bone tumours, with an incidence of 10–12% among all benign bone tumours. It was first described by Jaffe in 1935 (1). Its most common symptom is bone pain with an immediate response to salicylates or other nonsteroidal anti-inflammatory drugs (NSAIDs). Cases of spontaneous remission have been reported in studies on the natural history of lesions, but treatment is usually required to provide relief (2). Most lesions are located in lower extremities, especially metadiaphyseal parts of the femur and tibia (3). Around the circumference of the femoral neck and intra-articular regions are the most frequently involved areas. It is also common in the spine, hands and feet. Radiographically, an OO is observed as an intracortically located radiolucent nidus with a dense sclerosis surrounding it, but it may rarely show the intramedullary location. In computed tomography (CT), it appears as hypodense areas in the form of central calcification and perinidal sclerosis (4).

The gold standard treatment method for OO was surgery in the past. However, due to the difficulties in identifying the lesion intraoperatively and the need for long-term rehabilitation, treatment with percutaneous methods has become the first preferred treatment option today (5). Radiofrequency ablation (RFA) has been the first preferred minimally invasive method since its use, but in recent years, the number of studies reporting that microwave ablation (MWA) is also an effective and safe treatment method has been increasing. The main clinical advantages of MWA are higher temperatures and faster heating, shorter ablation times, larger ablation volumes and less heat sink effect compared to RFA (6,7). Several studies have been published describing the outcomes and side effects of MWA (8-10). However, only a few studies have investigated the effectiveness of the treatment according to the location of the nidus in the long bones (11,12). Proximal femur is one of the most common sites of primary benign bone tumors such as OO, and it becomes an important anatomical region due to its unique anatomy and biomechanics. Also, there is a high risk of pathological fracture after surgery due to anisotropy in this localization (13). In

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addition, lesions seen in the juxta-articular region of the femur may show different clinical and radiological symptoms from those seen in other regions. On the other hand, painful joint limitation of motion was observed in some cases after RFA treatment. In proximal femoral OOs, the combined effects of periarticular muscle contracture and synovitis may induce more complex skeletal deformity (14). Also, some studies have hypothesized that medications used for pain relief would be less effective due to secondary synovitis (15). In the light of all these facts, the management of OOs located in the proximal femur requires special expertise and follow-up.

The efficacy of MWA treatment of intra-articular and extra-articular OOs has previously been identified in some studies (16), but to our knowledge, no studies have yet compared the effectiveness of treating extra-articular lesions located in the long bones especially between proximal femur and the other regions of long bones. Therefore, the aim of our study was to assess the efficacy of MWA in the treatment of painful extra-articular OOs in long bones in a consecutive series of patients and to compare the technical and clinical success and complications according to their location.

2. Materials and Methods

Institutional review board approval was obtained for this retrospective study for all OOs treated with MWA between January 1, 2016, and June 1, 2020 at our single-centre tertiary care hospital. Thirthy consecutive MWA examinations were performed during the study period. In each OO cases, diagnosis was established by demonstrating a definite nidus along with perilesional cortical thickening on CT or bone marrow edema on magnetic resonance imaging (MRI) in patients with severe bone pain who clinically required treatment with NSAIDs almost every day to relieve pain. The decision to continue with MWA was made by a team including a radiologist and an orthopedic specialist. Patients who had high-risk anatomical lesions were excluded from ablation therapy. For example an osseous lesion in close proximity to the main vascular structures or having a nerve trace adjacent to the lesion. Additionally, patients who had insufficient information in the hospital information archive and who could not be reached by telephone were excluded from the study. Consequently, 23 patients (mean age 16.22 ± 7.89, range 2–35) were enrolled in the study. There were 14 women (60.9%) and 9 men (39.1%). We divided the patients according to the location of nidi into three groups as pertrochanteric, metaphyseal or diaphyseal regions in long bones.

All patients and/or their guardians were informed about the technique and its possible benefits and complications, and they signed a written consent form to undergo the procedure. CT was used as an imaging modality to locate the lesion, follow the needle trace, and reveal the final position of the probe. For all patients, general anaesthesia was applied in addition to local lidocaine at the ablation sites. All patients were treated using the Helios Microwave Ablation System H-1 (Canyon Medical, Jiangsu, China). In all cases, after the bony cortex was passed using an 11-gauge cortical drill, the 13-gauge core needle was advanced coaxially into the lesion nidus with imaging guidance. After inserting the microwave probe into the OO through a coaxial sheath, the sheath was retracted as far as possible from the probe tip (Fig. 1, 2). A minimum of three ablation cycles targeting 80°C were performed at 30 to 50 W for 30 seconds at 1-minute intervals. Patients who did not develop any complications were discharged on the same day of the procedure. For antibiotic prophylaxis, 2 g cefazoline was administered intravenously before MWA ablation and for the first 2–3 days after the procedure.

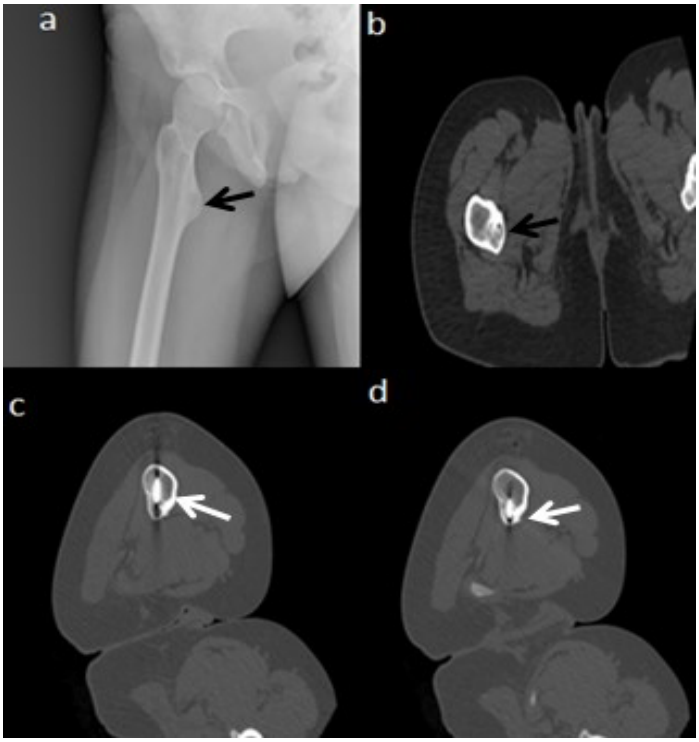

Fig. 1. 18-year old girl wtih osteoid osteoma of the right femur, (a) The AP plain radiographs and (b) Axial CT image shows the nidus at lesser trochanter (black arrow) with adjacent cortical thickening (c-d) The intraprocedural axial CT image shows the MWA antenna in the center of the lesion (white arrows)

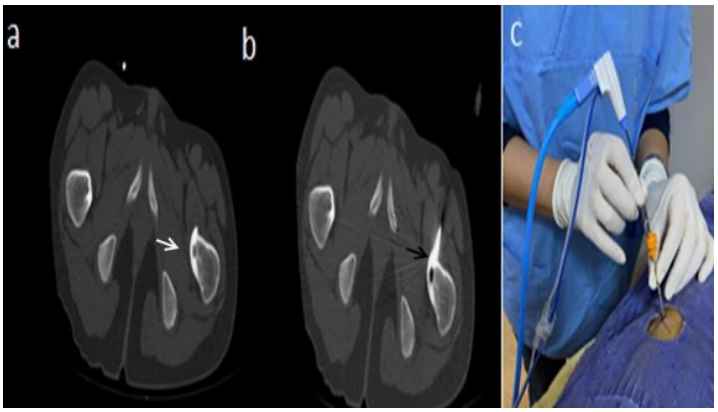

Fig. 2. Ablation of an osteoid osteoma of the left femur intertrochanteric region (a) CT image demonstrates the nidus (white arrow) (b-c) The intraprocedural axial CT image shows the MWA ablation probe being inserted into the nidus through a needle (black arrow)

Medical data and images were analyzed for age, gender, nidus size, date, duration, and location of the lesion in the pertrochanteric, metaphyseal, or diaphyseal regions of the long bones. A follow-up appointment is planned for all our patients for 1 and 6 months after the procedure. In the vast majority of patients, we prefer CT as a follow-up imaging modality to determine if ablation has been completed. However, in some cases where we want to show bone marrow edema or suspect infective conditions, we resort to MRI. Numerical pain scores (0–10) of the patients were recorded using a visual analog scale (VAS). Patients were grouped into three categories based on location of in long bones and treatment with MWA. Operation length, recurrence and success rates were compared between three groups. The success of each ablation was evaluated both clinically and technically.

Technical success was defined as the application of the target ablation temperature by reaching the ablation probe distal to the nidus. Clinical success was defined as the complete relief of pain without the use of painkillers in the sixth month follow-up of the patients. The complications were defined according to the Society of Interventional Radiology (SIR) guidelines (17). Patients were also called one year after the procedure for follow-up on any complications or recurrence of pain.

The study data were evaluated using SPSS for Windows 22.0 software (SPSS Inc. Chicago, IL). The compatibility of the variables with a normal distribution was examined using the Shapiro-Wilk test.

For analysis frequency, percentage, mean value, standard deviation and data range (min–max) were used. Categorical variables were indicated by number and percentage (%). For dependent groups, a comparison was conducted using the Wilcoxon signed-rank test; for independent groups, the independent samples t-test was used. In the comparison of continuous measurements between groups (three groups), by controlling the distributions, one way analysis of variance (ANOVA) was used for variables conforming to the normal distribution, and the Kruskal Wallis test was used for variables that did not fit the normal distribution. Pairwise comparisons were made using the Mann-Whitney U test and were evaluated using post-hoc Bonferroni correction. Spearman test was used for correlation analysis. Statistical significance was recognized as $p < 0.05$ for all tests.

3. Results

We included 23 patients with OOs in long bones. All procedures were completed successfully. Demographic and clinical data are summarized in Table 1.

The youngest patient in our series was 2 years old and the oldest was 35 years old. Of the lesions, 16 (69.6%) were located on the femur: 8 on the right side and 8 on the left. The most common location of tumours in the femur was the pertrochanteric region (34.8%). The average ablation duration was 48.04 (30–65) minutes.

Table 1. Patient demographic and clinical data (n=23)

Characteristic	Value
Age (years)	
Mean	16.22
Range	2-35
SD	7.89
Gender	
Male	14(60.9%)
Female	9 (39.1%)
Preprocedural pain (months)	18.78
Mean	2-72
Range	16.62
SD	
Nidus size (mm)	
Mean	5.61
Range	2-10
SD	2.17
Nidus location	
Pertrochanteric femur	8 (34.8%)
Diaphysial femur	5 (21.7%)
Metaphysial femur	3 (13%)
Metaphysial Tibia	4 (17.3%)
Diaphysial Tibia	2 (8.6%)
Metaphysial humerus	1 (4.3%)

SD: Standard deviation

In a two-year-old paediatric patient with a lesion in the tibia diaphysis, osteomyelitis developed in addition to the wound discharge and infection findings two weeks after the procedure. It was the only serious complication encountered in all procedures. The patient was hospitalized for osteomyelitis treatment and received intravenous antibiotics. The wound site was cleaned and he was discharged in a healthy condition. Another complication was mild femoral reversible postprocedural neurapraxia releated with lateral femoral cutaneous nerve in a patient with osteoid osteoma of the femur. Patient reported numbness and burning sensation on the anterolateral thigh for 6 months. Permanent neurological deficits or intervention-related mortality were not observed in any of the patients included in this study.

A nine-year-old patient with a lesion in her lesser trochanter developed bone marrow oedema after MWA. There was no osteomyelitis or skin lesion. The patient had only moderate pain for six months after the ablation. Then, by the one-year follow-up, her symptoms had resolved completely.

The results of 23 patients who underwent MWA are summarized in Table 2. The difference between preintervention and postintervention pain scores was statistically significant ($p < 0.001$). At the last one-year follow-up, OO-related pain had completely disappeared in all patients. Therefore, no additional imaging was required. Clinically, no recurrence was observed in any of the patients in the study

In comparing the pain scores by the location of each lesion,

no statistically significant difference was found between the first-day (p = 0.504) and first-week (p = 0.648) pain scores. However, there was a statistically significant difference between the first-month (p = 0.016), third-month (p < 0.001) and sixth-month (p = 0.001) pain scores.

Table 2. Outcome measurements, correlation between nidus location and clinical success

	Mean	Range	SD	P value	Post-hoc p value***
VAS score pre procedure					
Pertrochanteric[a]	9.75	9-10	0.463		
Metaphsial[b]	9.88	9-10	0.354	0.735*	-
Diaphysial[c]	9.71	9-10	0.488		
VAS score 1 day post procedure					
Pertrochanteric[a]	6.88	5-8	0.991		
Metaphsial[b]	7.75	5-10	1.699	0.504**	-
Diaphysial[c]	7.43	5-10	1.718		
VAS score 1 week post procedure					
Pertrochanteric[a]	4.5	4-6	0.756		
Metaphsial[b]	5.13	3-7	1.458	0.648*	-
Diaphysial[c]	4.86	2-8	1.864		
VAS score 1 month post procedure					
Pertrochanteric[a]	3	2-4	0.756		a-b 0.108
Metaphsial[b]	1.75	0-5	1.909	0.016*	a-c 0.003
Diaphysial[c]	0.86	0-2	1.069		b-c 0.384
VAS score 3 month post procedure					
Pertrochanteric[a]	2.75	2-6	1.389		a-b 0.001
Metaphsial[b]	0.25	0-2	0.707	<0.001*	a-c <0.001
Diaphysial[c]	0	0	0		b -c 0.350
VAS score 6 month post procedure					
Pertrochanteric[a]	1.5	0-4	1.309		a-b 0.004
Metaphsial[b]	0	0	0	0.001*	a-c 0.006
Diaphysial[c]	0	0	0		b-c 1

SD: Standard deviation. VAS: Visual analog scale. *Kruskal-Wallis test. **One-way ANOVA. *** We performed Bonferroni correction to compare groups as a post-hoc test. Accordingly. p<0.017 is statistically significant in paired comparisons.

Table 3. Correlation between pre and post-procedural pain and nidus size

	Nidus size ≤5 mm		Nidus size >5 mm		
	Mean±SD	Range	Mean±SD	Range	P value
VAS score pre procedure	9.8±0.42	9-10	9.7±0.43	9-10	0.862*
VAS score 1 day post procedure	7.1±1.19	5-9	7.54±1.66	5-10	0.49**
VAS score 1 week post procedure	4.8±0.78	4-6	4.85±1.72	2-8	0.796*
VAS score 1 month post procedure	2±1.41	0-4	1.85±1.72	0-5	0.821**
VAS score 3 month post procedure	1.1±2.02	0-6	1±1.15	0-3	0.695*
VAS score 6 month post procedure	0.7±1.33	0-4	0.38±0.76	0-2	0.658*

* Mann-Whitney U test, ** Independent samples t-test

Bonferroni correction was conducted as a post-hoc test in the paired comparisons between the three differently located groups. Accordingly, comparisons with p < 0.017 were considered statistically significant. It was determined that the statistically significant differences between the sites at the first, third and sixth months were due to the difference between the pertrochanteric lesions and the diaphyseal lesions.

The mean durations of the MWA procedures were found to be 57.50 + 4.62, 50 + 8.01 and 35 + 2.88 minutes for pertrochanteric, metaphysial and diaphyseal lesions,

respectively. While there was no statistically significant difference between the pertrochanteric and metaphysial groups in terms of procedure time (p = 0.059), there was a statistically significant difference between pertrochanteric lesions and diaphyseal lesions in procedure time (p = 0.001). There was also a statistically significant difference between the metaphyseal and diaphyseal groups (p = 0.001). Therefore, it was concluded that the difference between the operation time and the groups was likely due to the lesions in the diaphysis.

When nidi with a diameter of 5 mm or less and nidi larger than 5 mm were compared in terms of pain scores, no statistically significant differences were found between the scores at the first day, first week, first month, third month and sixth month (Table 3).

A statistically significant negative correlation was found between the duration of pain before the procedure and the first-day pain scores (p = 0.003, r = –0.592). A statistically significant negative correlation was also found between the duration of pain before the procedure and pain scores in the first week (p < 0.001, r = –0.721). However, correlations found with other pain scores are not statistically significant (Table 4).

Table 4. Correlation between preprocedural pain, VAS score 1 day post procedure and VAS score 1 week post procedure

	rho*	P value
Preprocedural pain (months) – VAS score 1 day post procedure	-0.592	0.003
Preprocedural pain (months) – VAS score 1 week post procedure	-0.721	< 0.001

* rho :Spearman's correlation coefficient

4. Discussion

Osteoid osteoma is a benign osteogenic tumor that accounts for 13.5% of all benign tumors and predominantly affects children and young adults (18). Although surgical removal of the nidus was used as the gold standard treatment method among the treatment options used for OO in the past, modern interventional methods such as RFA and MWA have lower complication rates and shorten the duration of hospital stay (19).

Our results confirm that percutaneous ablation is the treatment of choice for OOs, suggesting that there is little difference between procedure time, clinical presentation, follow-up and outcomes in terms of OO location in long bones. Our overall technique and primary clinical success (in terms of complete pain relief following MWA at 6 months) were 100% and 82.6%, respectively. These rates are in line with the findings of prior studies (3,5,9,12).

Most treatment failures are due to recurrent disease and are reported at a rate of 5.6% for all methods. Cantwell et al. (20) and Lee et al. (21) reported the success rate of surgical interventions as approximately 88-100% and the recurrence rate as 4.5-25% in their study. According to the results of a literature review (22), percutaneous thermal ablation of OOs with an overall success rate of 91.9% and an overall complication rate of 2.5% has been proven to be a safe and effective therapeutic alternative to open surgery.

Studies have reported that the recurrence rate decreased significantly after six months and reached very low rates, especially after two years (3). In our study, when we determined according to the symptoms of the patients in the mean follow-up period of one year, there was no recurrence in any of the cases.

Studies have concluded that even if there is a possibility of thermal risk, OOs can be safely treated with RFA. Vanderschueren et al. (23) reported that the only complication among the 97 participants in their study was skin necrosis, which resulted in a fistula in one patient. In their study, Lanza et al. (24) evaluated 27 articles including 1,772 patients and reported that 12 of 44 patients with complications had skin burns. Since RFA energy is transmitted by resistive heating, it spreads to the surrounding tissue, while heat production in MWA occurs by the rapid agitation of water molecules. It is important to minimize the procedure time to reduce the cumulative effect of anesthesia in pediatric patients. Therefore, it is possible to reach the target temperature in a shorter time with MWA, which allows faster tissue warming compared to RFA (25). There is also no potential for skin burns associated with pad placement in MWA (26). There were no skin burn complications in our series either. Our only serious complication was osteomyelitis in a two-year-old patient.

The proximal femur is one of the most common locations of primary benign bone tumours. Since tumours in this area are more commonly associated with clinical symptoms and serious complications as compared to other regions, numerous studies have focused on exposing the hip joint capsule or femoral neck (27). In addition, according to Campanacci (1), OOs were frequently encountered in the proximal femur in 25.4% of cases, while this rate was 40% in our series. The frequent localisation of the lesions in this region confirms the value of this study. In most studies (2,4,20,28,29) previously conducted on percutaneous treatment by drilling or thermoablation, no differentiation was made between the proximal femur and lesions located in other regions. The advantage of our range is that it focuses specifically on proximal femoral lesions.

Vanderschueren et al. (23) could not find any relationship between location and unsuccessful outcomes in their study, in which they grouped lesions as intra-articular or extra-articular and intracortical or extracortical according to their location. Rosenthal et al. (29), on the other hand, found that there was no statistically significant relationship between location (femur, tibia and other) and clinical outcome.

In this study, we classified the location of the osteoid osteomas as pertrochanteric, metaphyseal or diaphyseal in long bones. We found that the time it took for pain to disappear completely in pertrochanteric tumours was longer than in the

other groups. This difference is statistically significant and has not been previously described.

We can associate the presence of a more pronounced cortical reaction in lesions located in the diaphysis with a faster disappearance of pain. Heat insulation is easier in the ablation treatment of lesions with a better cortical surrounding. In lesions located in other regions (e.g. non-diaphyseal), since there is less accompanying cortical thickening, we predict that local ablation may be less effective, increasing the risk of local recurrence. However, no recurrence was observed in our series at one year.

We acknowledge some limitations in our study. First, although our study was the largest case series in the literature comparing lesions by location in long bones treated with MWA, it consisted of a relatively small number of patients. Second, we did not have histopathological confirmation; instead, we described lesions based on characteristic clinical presentation and imaging findings. However, as noted in previous studies in the literature, percutaneous pre-ablation bone biopsy may not be necessary in typical cases, as there is a significant percentage of non-diagnostic biopsy findings in OO, and most lesions that are similar to OO can be safely and successfully treated with thermal ablation (30). Finally, long-term follow-up data were not available in our study.

In conclusion, our study demonstrates that the CT-guided percutaneous MWA method is effective in the treatment of OOs located in long bones without recurrence. However, the management of pertrochanteric OOs requires special expertise and follow-up. In the future, more studies are needed to evaluate the long-term efficacy and safety of MWA for OO therapy, particularly in cases in pertrochanteric areas where the risk of local recurrence is heightened.

Conflict of interest

The authors declared no conflict of interest.

Ethical Approval: Ethical approval of this study was obtained from Ondokuz Mayıs University Hospital Institution Review Board and Ethics Committee prior to initiation this research study. Local Ethics Committee approval (date: 25/05/2021; approval number: 2021/163).

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