Percutaneous Microwave Ablation of Bone Metastases

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Treatment of Bone Metastases with Microwave Thermal Ablation

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ABSTRACT

Purpose: To retrospectively evaluate the feasibility, safety, and effectiveness of computed tomography (CT)–guided percutaneous microwave ablation (MWA) in patients with bone metastases.

Materials and Methods: Twenty-one patients with metastatic bone lesions were treated in 18 MWA sessions. In patients whose lesions contained fractures, or who had a high risk for fracture (48%; n = 10), MWA was followed by cementoplasty with polymethylmethacrylate injection. The positioning of the MWA antenna into the tumor was guided by CT. Treatments were performed under conscious sedation. All patients underwent clinical (self-reported Brief Pain Inventory [BPI]; scale from 0 to 10) and radiologic evaluation at baseline and 1 month after the procedure. The reported results are data from baseline to a follow-up period of 3 months.

Results: There were no complications. A reduction of pain and improvement in quality of life was observed in all patients as measured by BPI score. On average, the mean BPI score during the 3-month follow-up period was reduced by 92% (41%–100%). Thirteen of 18 patients (72%) were symptom-free, four patients (22%) were still symptomatic but with 85% lower average BPI scores (41%–95%), and one patient (6%) experienced a recurrence of symptoms.

Conclusions: Preliminary results suggest that MWA of bone metastases is a well tolerated, safe, and effective procedure. However, its efficacy still remains to be determined by medium- and long-term studies.

ABBREVIATIONS

BPI = Brief Pain Inventory, MWA = microwave ablation, NSAID = nonsteroidal antiinflammatory drug, PMMA = polymethylmethacrylate

Skeletal metastases are the most common cause of severe pain among patients with cancer. Bone pain remarkably compromises the patient's quality of life. This type of pain can be caused by periosteal stretching secondary to tumor growth, release of chemical mediators by tumoral cells, osteolysis, micro- and macrofractures, spinal cord compression, entrapment and nerve root infiltration, and/or compression caused by weakening of bone by tumor growth (1). The treatment options currently available to patients with bone pain from metastases are primarily palliative, in addition to systemic therapy for the underlying malignancy. These palliative treatments include the use of bisphosphonates, systemic analgesic agents, steroids, external-beam radiation therapy, and local surgery (2). A number of patients do not benefit from these conventional therapies, and pain relief may only be achieved 4–12 weeks after the initiation of treatment (3). Because of these patients' short life expectancy and poor quality of life, a minimally invasive approach is desirable. During the past decade, percutaneous ablation has emerged as an effective minimally invasive local treatment alternative to the aforementioned conventional therapies (4). As a wide range of pain treatment options are available to patients with skeletal and soft-tissue metastases, the selection of the most appropriate ablative technology requires proper patient and lesion selection, knowledge of relevant anatomy, and an understanding of the advantages and limitations of the specific technique.

The principal indication of image-guided musculoskeletal tumor ablation is for the palliative treatment of painful metastases secondary to advanced cancer disease. Microwave energy radiates into the tissue through an interstitial antenna

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that functions to couple energy from the generator power source to the tissue. As a result of the radiation energy emitted from the antenna, direct heating occurs in the adjacent tissue volume. Bone tissue exhibits low conductivity and high impedance, and, therefore, microwaves, which are relatively insensitive to high impedance, may present a relative advantage in the treatment of musculoskeletal tumors. Additionally, multiple microwave antennas can be powered simultaneously to take advantage of the thermal synergy that occurs when these antennas are placed in close proximity (5,6). Thermal ablation can destroy the tumor but may also further weaken the bone involved. If this bone is weight-bearing and there is a risk of pathologic fracture, consolidation with cementoplasty or surgery is needed. Percutaneous injection of polymethylmethacrylate (PMMA) provides pain relief and strengthens the bones in patients with malignant bone tumors (7). Because of its mechanical properties, this cement is suitable for the treatment of fractures involving weight-bearing bones, such as the vertebral body and acetabulum, and in any bones subject to compression forces. Although the use of microwave ablation (MWA) has been reported to help surgical resection of osteosarcomas (8), no data are available about its percutaneous use in musculoskeletal tumors. The aim of the present study is to evaluate the technical success, effectiveness, and possible complications of MWA treatments in patients with painful bone metastases.

MATERIALS AND METHODS

Institutional review board approval is not required at the authors' hospital for retrospective case studies such as the present study, and informed consent to perform MWA of bone cancer, alone or with osteoplasty, was obtained from all patients.

From July 2011 to January 2012, 18 consecutive patients with skeletal metastatic lesions (eight men and 10 women; mean age, 63 y) underwent computed tomography (CT)–guided percutaneous MWA of bone symptomatic metastases. Seven patients had previously been treated with radiation therapy, three patients with radiation therapy and chemotherapy, and seven with chemotherapy alone. In all these patients, pain had proven refractory to conventional approaches.

Before the ablation treatment, all patients received analgesic therapy consisting of opioid agents or a combination of opioid and nonsteroidal antiinflammatory drugs (NSAIDs), and analgesic agent use was monitored before treatment and at 1, 4, and 12 weeks thereafter for all patients.

Patients were selected based on the following criteria: Brief Pain Inventory (BPI) score greater than 4, lesions not responding to chemotherapy and/or radiation therapy at least 3 weeks before the ablation session, chemotherapy-associated complications that required cessation of treatment, lesions adjacent to structure sensitive to irradiation, life expectancy greater than 2 months, and ineligibility for surgical treatment.

Table. Bone Metastasis Classification with Regard to Primary Malignant Lesion and Site of Skeleton Involved

Site/Primary Neoplasm	n	Site of Metastasis	n
Penis	1	Acetabulum	1
NSCLC	8	Scapula	1
		Spine	1
		Pelvis	4
		Ribs	3
Thyroid	2	Spine	1
		Pelvis	1
Breast	7	Pelvis	8
		Spine	1
Total	18	–	21

NSCLC = non–small-cell lung cancer.

Fifteen patients had single lesions and three had two lesions each, resulting in a total of 21 metastases. The topographic distribution of the lesions and their originating primary malignancies are summarized in the **Table**. Lesion diameters ranged between 2.2 cm and 12 cm (mean ± standard deviation, 5.3 cm ± 3.2).

All treated lesions were osteolytic, with a combination of bone destruction and soft-tissue masses. All patients underwent a preliminary contrast-enhanced magnetic resonance (MR)-imaging study and/or CT scan to properly assess the site, size, and radiologic aspects of the lesion(s).

We considered patients to be at a high risk for fractures if their lesions involved just one of these criteria: bones subjected to load (eg, vertebrae, head and neck of femur, and acetabulum), disrupted the cortical bone with tumor tissue extending from the bone, and were extensively osteolytic.

The oncologist and radiologist who administered MWA also performed physical examination of the patients. Pain assessment was obtained through the BPI (9) and monitored at baseline and in the following weeks (1, 4, and 12 weeks after the procedure), for a total follow-up time of 3 months. The BPI score was obtained through the Pain Severity Score Questionnaire, which rated pain on a scale from 0 to 10 to indicate the intensity of pain. In all patients, drug therapy (eg, NSAIDs and opioid agents) was interrupted after 1 week. If symptoms persisted or worsened, drug therapy was resumed.

Radiologic follow-up consisted of contrast-enhanced CT or MR imaging 1 month after the procedure. No further radiologic evaluations were performed in the absence of new symptoms. In all patients, radiological imaging was performed 1 month after treatment, primarily to highlight the presence of any residual untreated tumor that may present focal contrast enhancement rather than to assess the recurrence of disease (in view of the short time since treatment).

MWA TECHNIQUE

Percutaneous MWA was performed by using a 2.45-GHz microwave generator (AMICA-GEN; HS Hospital Service,

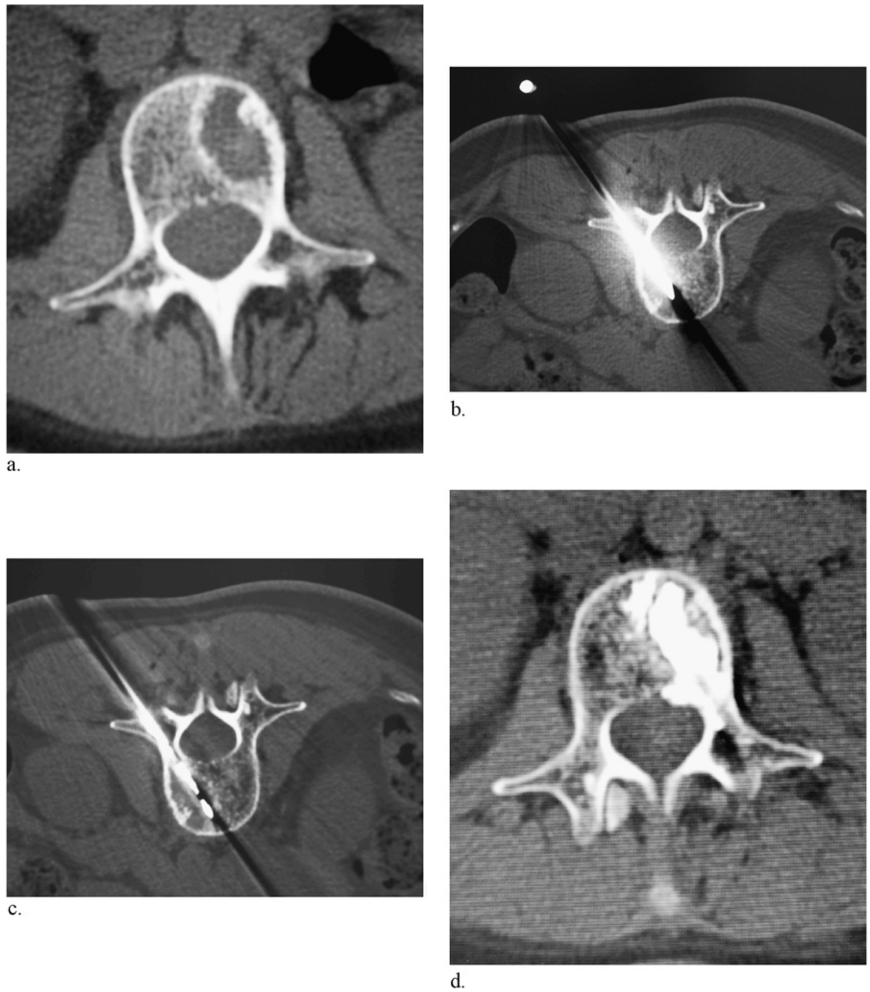

Figure 1. Lumbar vertebral metastasis from breast cancer. **(a)** Axial CT image shows a lytic lesion at L2. **(b)** Axial CT image demonstrates placement of vertebroplasty needle into the vertebral body at the level of osteolysis. **(c)** Axial CT image demonstrates positioning of the microwave antenna within the osteolytic lesion, with retraction of the cannula. **(d)** Final result after MWA and vertebroplasty with PMMA.

Aprilia, Italy) with energy delivered via a 14- or 11-gauge, minichoked, water-cooled interstitial antenna (HS AMICA; HS Hospital Service). For synchronous, double-antenna MWAs, two generators were used, each driving an individual antenna. The combined action of the patented minichoke (a miniaturized quarter-wave impedance transformer for reflected wave trapping) and probe shaft cooling system ($>$ 50 mL/min of room-temperature saline solution perfused by an automated peristaltic pump built into the microwave generator) prevented the back-heating phenomena typical of conventional MWA systems. A single 14-gauge antenna was used to treat tumors less than 3.5 cm in maximal diameter, and complete tumor elimination was achieved. To treat tumors at least 3.5 cm in maximal diameter, one antenna was used or two antennae were operated simultaneously. In some patients, a 10-gauge bone marrow biopsy needle (Stryker, Kalamazoo, Michigan) was used to pierce the bone cortex and served as a coaxial introducer for the antenna to comfortably reach the osteolytic lesion. When the antenna was in the tumor, the introducer was retracted before energy delivery was initiated so as not to interfere with microwave emissions by the active probe tip. We used 20-cm long microwave antennas to allow a sufficient retraction of the cannula from the ablation area. Upon completion of ablation, the antenna was withdrawn and the introducer was left in situ and subsequently used for the osteoplastic procedure (Fig 1). In cases in which the cortical bone surrounding the metastasis was eroded or interrupted by the tumor, an 11-gauge antenna was directly inserted into the target without the use of a coaxial introducer (Fig 2).

MWA PROCEDURE

In all patients, MWA was performed under CT guidance, with 5-mm collimation at 80–140 mA (SOMATOM Sensation, Siemens, Forchheim, Germany). In complex cases, and cases in which thermal ablation and MWA were combined, dual guidance with CT and fluoroscopy was used to allow precise needle placement, increase operator comfort, and reduce the rate of complications. A board-certified interventional radiologist performed all treatments. Throughout the

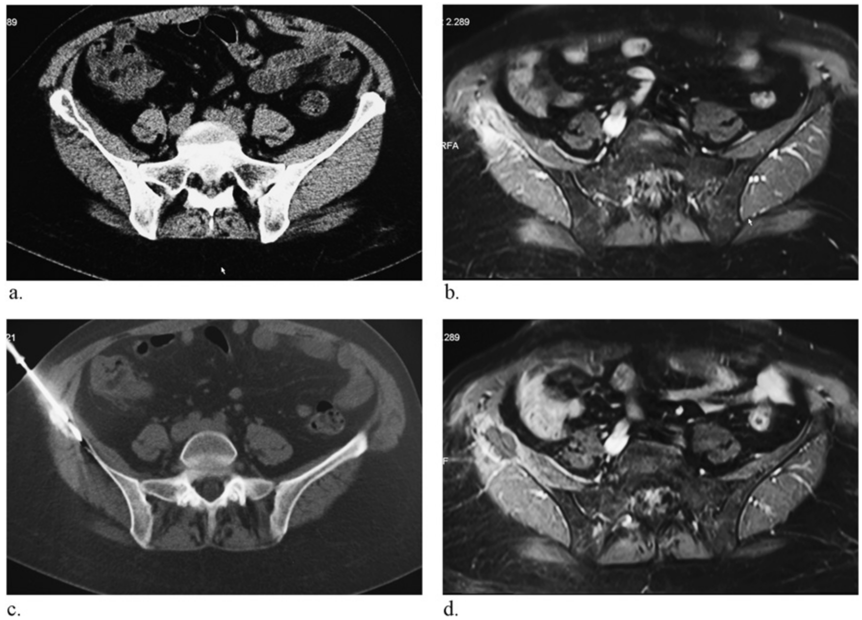

Figure 2. Right iliac metastasis from breast cancer. **(a)** Axial CT image shows a lytic metastasis in the right iliac bone. **(b)** T1-weighted MR scan with fat suppression after gadolinium infusion shows strongly positive lesion enhancement. **(c)** Axial CT scan performed during positioning of the 11-gauge needle into the bone to be treated. **(d)** T1-weighted MR scan with fat suppression after gadolinium infusion (1 mo after MWA) shows an area with intralesional hypointense coagulation necrosis surrounded by a ring of inflammation-associated enhancement.

procedure, patients were under conscious sedation, usually achieved through continuous intravenous infusion of fentanyl 0.1 mg/2 mL diluted 1:10 with saline solution and through local anesthesia comprising subcutaneous injection of 2% lidocaine hydrochloride. The choice of probe was at the discretion of the interventional radiologist and was based on several factors, including, but not limited to, tumor size, morphology, location, adjacent structures, and access route.

In the 18 ablation sessions, a single antenna was used in 33% of sessions (n = 7), and two antennas were used in 67% of sessions (n = 14). In patients at high risk for fracture (55%; n = 10), the ablation treatment was combined with cementoplasty with PMMA injection (mean, 6.8 cm^3; range, 2–16.5 cm^3).

RESULTS

Technical success, defined as the ability to achieve complete ablation at the interface between soft tissue and bone and inject cement in cases of combined treatment, was achieved in 100% of cases. The mean procedure time was 7 minutes ± 5, and the net delivered power was 50 W ± 20 (mean ± standard deviation) at the end of the probe.

Postprocedural CT (without contrast enhancement) did not demonstrate any major complications, such as hemorrhage or thrombosis of neighboring veins. At 24 hours after treatment, all patients were discharged in stable condition without complications. In all patients, contrast-enhanced CT scans performed 1 month after the procedure showed no significant changes compared with the baseline scans.

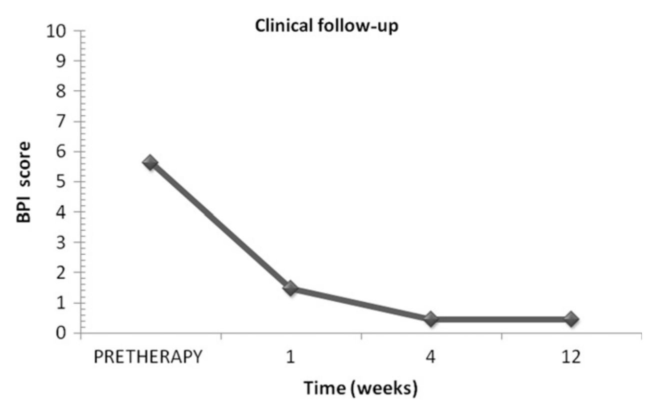

Figure 3. BPI score as a function of time.

The mean BPI score on the day of the procedure was 5.6 ± 1.2 (range, 0–10). No patients reported an increase in pain during the first 24 hours following the procedure. Clinical evaluation of the patients showed that their symptoms were reduced 1 week after treatment. The mean BPI score 7 days after the procedure was 1.32 ± 1.35, with a mean reduction of 77%. Four weeks after treatment, and 3 weeks after the cessation of the patients' usual pain therapies, the mean BPI score was 0.45 ± 0.7. Nine of 18 patients (50%) were completely pain-free, and the other patients reported a 64% reduction in BPI score. These patients resumed pain treatment with NSAIDs because their symptoms were not severe. Twelve weeks after the MWA procedure, the mean BPI score was 0.45 ± 1.0 (Fig 3), with a mean reduction of 92% (range, 41%–100%). Thirteen of 18 patients (72%) were symptom-free and did not resume any therapy. Symptoms continued in four patients (22%)—of whom two were treated with MWA alone and two were treated with a combination of MWA and cementoplasty—but with a mean 85% reduction in BPI score (range, 41%–95%). Only one patient (6%) had a recurrence of symptoms.

In the patients treated with MWA and cementoplasty, no fractures were observed in the 3 months following treatment.

DISCUSSION

Bone metastasis is a common problem that affects patients with cancer, occurring in as many as 30% of patients with epithelial cancers. These metastases originate from primary tumors in the prostate or breast in 70% of cases, the lung or kidney in 20%–30% of cases, and the rectum, colon, ovary, and pancreas in 10% of cases (10). Complications from skeletal metastases include intractable pain, fracture, and decreased mobility, which may reduce performance status and quality of life. In patients with cancer, pain originating from bone metastases can be difficult to treat, although a number of treatment options are available. Treatment of local disease may reduce pain in these patients, who, in most cases, have a life expectancy of months. Such treatment must be fast, safe, effective, and tolerable (11).

Published studies have shown the application of MWA in several tissues, such as the liver, lung, kidney, and, more rarely, the pancreas, adrenal glands, and bone (12–15). A limited number of reports regarding the use of MWA to treat patients with painful metastases have demonstrated promising results (16,17).

The present study evaluated the applicability of MWA therapy to treat a group of patients with metastatic bone pain and the possibility of its combination with cementoplasty. In 18 sessions, MWA treatment proved to be minimally invasive, effective, safe, and well tolerated by patients. A reduction of pain and improvement in the quality of life was reported as early as 1 week after the procedure, as measured by BPI score.

During clinical follow-up, patients reported reduction in the BPI score between the first and fourth weeks despite discontinuation of pain therapies. This result was maintained on follow-up between the first and third months. During the 12-week follow-up period after the procedure, only one patient (6%) experienced a recurrence of symptoms.

The present study is limited by the relatively small number of patients and short follow-up period. The clinical follow-up period of this study was 12 weeks, a period we believe is sufficient to demonstrate the efficacy of MWA in the palliation of painful bone metastases alone or in combination with cementoplasty.

Future studies with extended clinical follow-up periods are needed, although these studies would be limited by the short life expectancy of these patients. However, given the palliative effects of MWA demonstrated in the present study, larger studies are warranted in attempts to replicate its results.

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