Pain Medicine

Pain Medicine 2013; 14: 1873–1881
Wiley Periodicals, Inc.

Analgesic Effects of Microwave Ablation of Bone and Soft Tissue Tumors Under Local Anesthesia

Adrian Kastler, MD, MSc,*† Hussein Alnassan, MSc,† Philippe L. Pereira, MD, PhD,¶ Guillaume Alemann, MD,†‡ Daniel-Ange Barbé, MD,†‡ Sébastien Aubry, MD, PhD,†‡ Florence Tiberghien, MD,§ and Bruno Kastler, MD, PhD†‡

*Neuroradiology Department, CLUNI, University Hospital, Grenoble;

†I4S Laboratory—EA 4268-IFR 133, Franche Comté University, Besançon;

‡Radiology and Interventional Pain Unit, CHU Jean Minjoz, Besançon;

§Pain Evaluation and Treatment Unit, University Hospital Jean Minjoz, Besançon, France;

¶Department of Radiology, Minimally Invasive Therapies and Nuclearmedicine SLK-Kliniken-Academic Hospital, Ruprecht-Karls-University, Heidelberg, Germany

Reprint requests to: Adrian Kastler, MD, I4S Laboratory, IFR 133 EA 4268, Franche Comté University, 1 place St Jacques, 25000 Besançon, France. Tel: (+33) 6-75-4967-38; Fax: (+33) 381-668-495; E-mail: adriankastler@gmail.com.

Disclosure: Authors have nothing to disclose.

No financial support or conflicts of interest are declared.

Abstract

Objective. To assess the feasibility and efficacy of microwave ablation (MWA) of painful refractory bone and soft tissue tumors performed under local anesthesia.

Study Design. A retrospective study between 2011 and 2013.

Setting. A single center, Academic Interventional Pain Management Unit.

Subjects. Fifteen patients with 25 refractory painful bone (N = 19) or soft tissue (N = 6) tumors treated with MWA were consecutively included.

Method. Local Institutional Review Board approval was obtained, and written informed consent was waived. Lesions included spinal (N = 3), sacral (N = 4), and extraspinal (N = 18) locations. Pain was measured on a visual analog scale (VAS) from 0 to 10 before and immediately after procedure, at 1 week, and on a monthly basis following procedure. MWA procedures were always performed under computed tomography guidance and local anesthesia along with nitrous oxide inhalation.

Results. Mean ablation time was 4.09 minutes (range 1–11) with an average of 4.2 cycles with a mean ablation power of 60 W. Preprocedure mean VAS score was 7.2 ± 0.97 (range 6–9). Follow-up postprocedure VAS scores were as follows: day 0: 1.64 ± 1.86, day 7: 1.82 ± 1.79, month 1: 2.05 ± 2.03 (14/15 patients), month 3: 2.13 ± 1.81, month 6: 2.36 ± 2.17; and were statistically significant ($P < 0.001$). Mean pain relief was 5.5 months.

Conclusion. MWA is feasible, safe, and effective in the management of painful refractory bone and soft tissue tumors. It may therefore be considered as a potential alternative to existing percutaneous ablation techniques in the management of bone and soft tissue tumors.

Key Words. Microwave Ablation; Bone Tumors; Local Anesthesia; CT Guidance; Soft Tissue Tumors

Introduction

Bone metastases are the most frequent malignant bone tumors occurring in up to 70% of all cancer patients [1]. Skeletal metastases represent the most frequent cause of pain in patients with neoplasms [2] and up to 90% of cancer patients will develop cancer-related pain [3]. Many

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024

of these patients suffer from intolerable pain, and quality of life is markedly disturbed despite specific management. Therefore, quick pain relief has become a priority in these patients suffering from refractory bony pain. Conventional management mainly includes analgesics, chemotherapy, hormonal therapy, radiopharmaceutical therapy, radiotherapy, and surgery [3,4]. These last two decades, image-guided interventional techniques have emerged with satisfactory results in the management of osseous neoplasm such as cementoplasty, radiofrequency (RF) [5], combined RF and cementoplasty [6,7], and cryotherapy [8]. However, the use of percutaneous microwave ablation (MWA), which has been described to treat various types of tumors (liver [9,10], lung [11], kidney [12], or thyroid [13]), has not yet been described in the management of bone and soft tissue tumors. Therefore, the objective of this study is to assess the feasibility, safety, and efficacy of microwave (MW) thermal ablation of bone and soft tissue tumors under computed tomography (CT) guidance.

Material and Methods

Local Institutional Review Board approval was obtained, and written informed consent was waived. Medical records of patients were reviewed by one of several authors, and the following data were collected and evaluated: demographic and clinical data, tumor characteristics, and information on pain.

Patient and Tumor Characteristics (Tables 1 and 2)

Fifteen patients with 25 bone or soft tissue tumors treated with MWA were included in this retrospective study between March 2011 and January 2013. All included patients presented with painful bone or soft tissue lesions refractory to all previously attempted conventional therapies including opioids, hormone therapy, chemotherapy, or radiotherapy. Decision to perform MWA was taken in a multidisciplinary staff including radiologists, pain physicians, oncologists, and palliative care physicians. All patients suffering from one or more painful bone or soft tissue tumor refractory to other therapies were eligible for MWA treatment if the tumor was considered percutaneously accessible.

Our cohort consisted of 15 patients (11 men, 4 women, mean age: 67.7 years old) who underwent 25 MWA with a spectrum of primary (N = 3) and secondary lesions (N = 22). The mean Karnofsky performance status was 62 (range 30–90). Four patients presented with soft tissue neoplasm (N = 6), and the remaining 11 patients suffered from bone malignancies (N = 19). Among the 11 patients with bone lesions, four patients presented with five sclerotic lesions and seven patients with 14 osteolytic lesions. In three patients, adjunct cementoplasty was performed. The number of treated lesions in one patient varied from one to three: one lesion, eight cases; two lesions, four cases; three lesions, three cases. Mean tumor size (maximum diameter) was 47 mm ± 22.4 (range 12–120 mm).

Procedure

All procedures were accomplished by experienced physicians with percutaneous thermal ablation. MWAs were performed under CT guidance on an outpatient basis (Somatom Sensation 64, Siemens Medical Solutions, Erlangen, Germany). Patients were placed on either supine, prone, or lateral position depending on lesion site. Procedures were performed under strict aseptic conditions after skin sterilization and standard draping techniques. All 25 procedures were performed under local anesthesia and light conscious sedation using nitrous oxide inhalation. In addition, in case of procedural pain, intravenous injection of either paracetamol (1 g) or nalbuphin (20 mg) (three cases) could be used on demand.

Target lesions were identified on an initial planning CT, and optimal skin entry point along with needle pathway was determined. Local anesthetics (a mixture of fast and slow-acting anesthetic [lidocaïne hydrochloride 1% {1/3} and ropivacaïne hydrochloride 0.25% {2/3}]) were then administered from skin entry point to tumor surroundings. In most cases (20/25), intratumoral injection of anesthetics was also performed: 2–12 mL of the same mixture as described earlier, depending on tumor size.

In cases of osseous osteosclerotic lesions, a 13G bone needle (t'CD II, Thiebaud, Margenciel, France; or OsteoSite, Cook, Bloomington, IN, USA) was inserted under step-by-step CT guidance until needle tip was correctly situated at defined target (generally at the center of the lesion). The MW antenna shaft (1.8 mm diameter, 14 or 19 cm long) was then coaxially inserted into the bone needle (Figure 1). In cases of soft tissue (Figure 2) or lytic bone lesions (Figure 1), the MW antenna was directly inserted into the lesion. The MW generator used was an Acculis 2.45 GHz MTA system® (Microsulis Medical Ltd, Hampshire,UK; AngioDynamics, Latham, NY, USA). No recommendations from manufacturer were available for bone lesion. Therefore, manufacturer's recommendation for liver lesions were initially followed and adapted throughout our own experience. MWA power was set between 30 and 180 W and lasted from 1 to 13 minutes depending on lesion size. Short repeated MW cycles (30 seconds to 5 minutes) were performed depending on patients' tolerance and effect on tissue seen on CT scan controls. The ability to accurately place the MW antenna at the center of the lesion and perform MWA was defined as technical success. Details on MWA procedures are given in Table 1. In cases of large tumors (>5 cm), MWA antenna position could be modified if needed to obtain overlapping ablation zones. In three cases, several MWAs were performed in one session.

Out of the 25 treated lesions, 17 were located in proximity to skin (<3 cm). In these patients, a sterile glove was filled with iced water and carefully disposed around the antenna shaft skin entry point to avoid skin burn (Figure 1).

In cases of spine lesions, lower limb clinical examination (motor and sensory) was performed between MWA

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024

Table 1 Details on tumors and procedures characteristics

	Lesion Type							MWA Characteristics		
Patient	Soft Tissue/ Bone	Metastasis	Primary Neoplasm	Lytic/Sclerotic Lesion	Location/Lesion Number	<3 cm Skin	Lesion Size	Number of MWA cycles	Mean Power (W)	Total Ablation Time
1	Soft tissue	Yes	Melanoma	NA	Right axillary mass	Yes	120 × 70	4	150	11
2	Soft tissue	Yes	Leiomyosarcoma	NA	Right L3 paraspinal muscular lesion/1	Yes	25 × 25	4	60	2
					Right L4 paraspinal/2	Yes	18 × 18	4	50	2
					Left periscapular/3	Yes	53 × 48	6	50	5
3	Bone	No	Osteosarcoma	Lytic	Right clavicle	Yes	90 × 83	5	60	5
4	Bone	Yes	Lung	Lytic	Right II rib/1	Yes	23 × 12	4	80	2
					Right III rib/2	Yes	43 × 15	4	80	2
					Right XI rib/3	Yes	55 × 28	4	100	4
5	Soft tissue	No	Lung	NA	Left supraclavicular	Yes	40 × 30	6	60	3
6	Bone	Yes	Lung	Lytic	Left VII rib/1	Yes	54 × 26	2	60	5
					Left VII rib/1	Yes	54 × 26	2	60	5
					Left VIII rib/2	Yes	30 × 15	1	60	1
7	Bone	Yes	Lung	Lytic	Right sacral wing	No	63 × 32	2	60	4
					Right sacral wing	No	70 × 40	7	60	6
8	Bone	Yes	Thyroid	Lytic	Left scapula/1	Yes	80 × 30	13	60	6.5
					Right VIII rib/2	Yes	40 × 36	6	50	4
9	Bone	Yes	Prostate	Sclerotic	L2	No	36 × 30	4	30	2
10	Bone	No	Myeloma	Lytic	Left sacral wing	No	35 × 30	5	50	2.5
11	Bone	Yes	Kidney	Sclerotic	D6	No	0.6 × 20	5	50	2.5
12	Soft tissue	Yes	Esophagus	NA	Left paravertebral T5-T9	Yes	62 × 62	4	160	8
13	Bone	Yes	Lung	Sclerotic	L3	No	12 × 10	1	60	2
14	Bone	Yes	Hepatocarcinoma	Lytic	Sternum/1	Yes	56 × 53	3	60	7
					Sternum/2	Yes	37 × 30	3	60	3
15	Bone	Yes	Lung	Sclerotic	Left sacral wing/1	No	40 × 28	6	60	6
					Left iliac bone/2	No	17 × 12	1	70	1

MWA = microwave ablation; NA = not applicable.

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024

Table 2 Details on patient demographic, clinical and pain data

Patient/ Sex/Age		KPS	VAS prior MWA	VAS after MWA						Pain Relief Duration	Procedural Pain	Analgesic Drug Administration	
				Day 0	Day 7	Month 1	Month 3	Month 6	Month 12			Before procedure	After Procedure
1/M/40		70	8	4	4	7				1	Not painful	Oral opiates	NSAID
2/F/70	MWA-1	90	8	0	0	0	0	0	0	22	Not painful	Oral opiates	None
	MWA-2 Lesion 1	90	8	0	0	1	1	1	1	13	Painful	Oral opiates	None
	Lesion 2	90	8	0	0	2	2	2	1	9	Not painful	Oral opiates	None
3/F/77		50	8	0	1	1	1	1		6	Not painful	Oral opiates	None
4/M/72	Lesions 1 and 2	40	7	2	2	2				1	Tolerable	IV opiates	NSAID
	Lesion 3		7	1	1	1					Tolerable		NSAID
5/M/67		40	7	2	2	2				1	Very painful	Oral opiates	NSAID
6/M/70	MWA-1	50	6	2	2	2	2			3	Tolerable	Oral opiates	None
	MWA-2 Lesions 1 and 2	40	6	1	2	2	2			3	Tolerable	Oral opiates	None
7/M/63	MWA-1	80	6	0	0	0	0	0		5	Very painful	Oral opiates	None
	MWA-2	70	6	0	2	2	2	2		6	Not painful		None
8/F/80	Lesion 1	50	9	4	4	4	4	4		6	Not painful	Oral opiates	None
	Lesion 2		8	3	3	4	4	4			Tolerable		None
9/M/70		60	8	2	2	3	3	3		6	Not painful	Oral opiates	NSAID
10/M/84		30	8	4	4					0.5	Not painful	IV opiates	Oral Opiates
11/M/65		70	7	7	7	7	7	7	7		Tolerable	Transdermic opiates	Transdermic Opiates
12/M/59		50	8	2	2	2				1	Tolerable	Oral opiates	None
13/F/80		90	5	2	2	0	2	2		4	Not painful	Oral opiates	NSAID
14/M/52	Lesions 1 and 2	50	7	0	0	1				1	Not painful	IV opiates	None
15/M/66	Lesion 1	70	7	0	0	0	1	1		6	Not painful	Oral opiates	None
	Lesion 2		7	0	0	0	1	1			Not painful		
Mean		616	7.23	1.64	1.82	2.05	2.13	2.36		5.5			
SD		19.6	0.97	1.86	1.79	2	1.8	2.17		5.2			

KPS = Karnosky performance status; MWA = microwave ablation; NSAID = nonsteroidal anti-inflammatory drug; VAS = visual analog scale.

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024

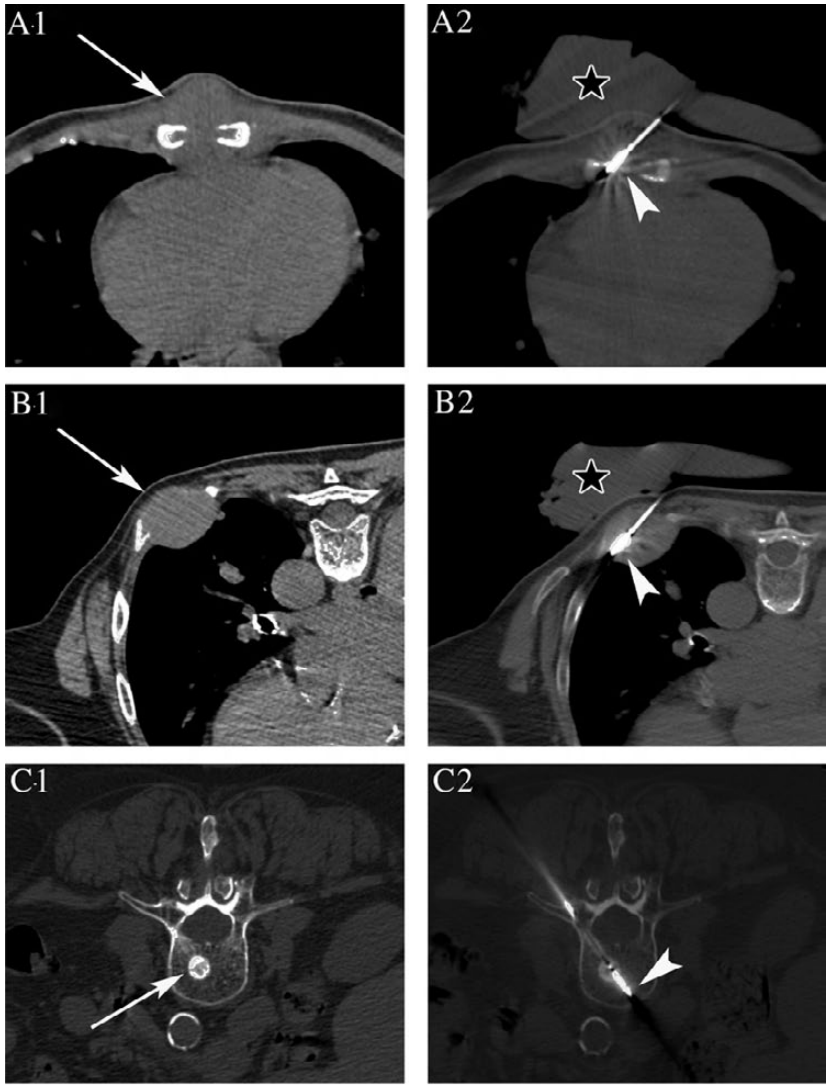

Figure 1 Examples of treated bone lesions: (A) Patient 14: A1, computed tomography (CT) slice showing a sternal osteolytic lesion (white arrow) before microwave (MW) ablation; A2, CT slice showing accurate antenna shaft placement in the center of the lesion (white arrow head). Note the presence of a sterile glove filled with iced water in this lesion situated close to the skin (black star) to avoid skin burn. (B) Patient 6: B1: CT slice showing an osteolytic lesion of the left 7th rib (white arrow) prior MW ablation; B2, CT slice showing accurate antenna shaft placement in the center of the lesion (white arrow head). Here again, note the presence of a sterile glove filled with iced water (black star). (C) Patient 13: C1, CT slice showing an osteosclerotic lesion of L3 vertebrae (white arrow); C2, CT slice showing accurate transpedicular approach antenna shaft placement in the center of the lesion (white arrow head).

sessions, and patients were instructed to alert us in case of lower limb pain or paresthesia. Technical success was defined as the ability to successfully place the MW antenna shaft in the center of the lesion and to undergo MWA.

Pain

Pain was assessed using visual analog scale (VAS) scores ranging from 0 (no pain) to 10 (most severe). A score of less than 2 was graded as mild pain, a score between 2 and 5 was graded as moderate pain, and a score above 5 was graded as severe. In case of multiple tumors in one patient, VAS scores were noted for each lesion. However, in case of lesion situated very close (patients 4, 6, and 14, lesions 1 and 2), one VAS score was noted. VAS scores were assessed face-to-face by authors immediately before and after each procedure (day 0) and at 1 week postprocedure (day 7). Data were noted in patient's medical record. Regular monthly follow-up clinical examination were then scheduled after procedure with either interventional radiologists or pain physicians/palliative care physicians. Moreover, intraprocedural pain was noted and graded as: not painful, tolerable pain, very painful.

Analgesic drugs prescribed at baseline and at follow up were classified as none, nonsteroidal anti-inflammatory drugs (NSAIDs), oral, transdermal, or intravenous opioids.

Statistical Analysis

Continuous variables are expressed as mean ± standard deviation. A paired Student's *t* test was used to evaluate the parameters before and after MWA at scheduled follow up. Values for *P* of less than 0.05 were considered statistically significant. All statistical analysis was performed using Systat version 12 (Systat Software, Chicago, IL, USA).

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024

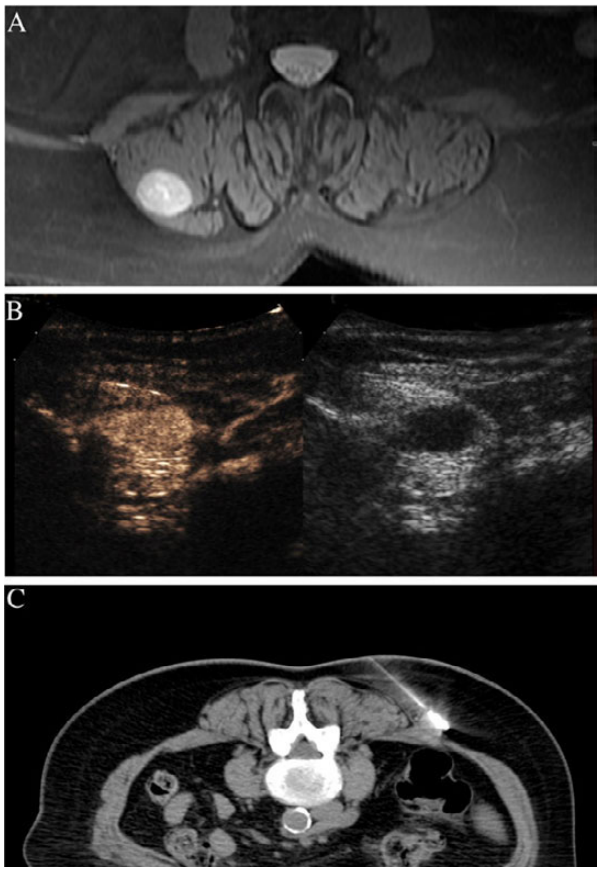

Figure 2 Example of a treated soft tissue tumor in a 70-year-old female patient suffering from a leyomyosarcoma painful metastase (microwave ablation [MWA] 1, patient 2). (A) Preprocedure magnetic resonance imaging showing T2 Weighed imaging hyperintense intramuscular right paravertebral muscle lesion. (B) Contrast ultrasound realized immediately before the procedure confirmed a highly enhancing nodular lesion. (C) Computed tomography slice during procedure showing MWA antenna shaft accurately located at target site.

Results

Procedure (Table 1)

Technical success was 100%. Mean ablation time was 4.09 minutes (range 1–11) with an average of 4.2 cycles per ablation lasting from 30 seconds to 5 minutes, with a mean ablation power of 60 W (range 30–180 W). Procedure was considered not painful in 13 cases, tolerable in 9 cases, and painful in 3 cases.

Pain (Table 2)

Preprocedure mean VAS score was 7.2 ± 0.97 (range 6–9) and was therefore classified as severe. Follow-up postprocedure VAS scores were as follows: day 0, 1.64 ± 1.87 ($P < 0.001$); day 7, 1.82 ± 1.79 ($P < 0.001$); month 1, 2.05 ± 2.03 ($P < 0.001$, 14/15 patients, one patient died 2 weeks after procedure); month 3, 2.13 ± 1.81 (($P < 0.001$, 9/15 patients); month 6, 1.80 ± 1.80 (7/15 patients). Twelve-month VAS scores were available in only three patients.

In one case, no pain relief was achieved at day 0, day 7, and month 1 follow-up examinations. Follow up was therefore discontinued, and treatment was considered a failure. In the remaining 14 patients (24/25 MWA), treatment was considered effective with a decrease of pain >50% on VAS scores lasting for a mean duration of 5.5 months (range 0.5–18 months). Pain medication were discontinued in 8 of 15 patients after procedure; opioids were replaced by NSAIDs in 5 of 15 patients and continued in three cases.

Side Effects

We report one major complication following MWA. One patient presented persistent pain 3 weeks after procedure. CT scan performed showed the occurrence of a soft tissue abscess at ablation site (right axillar). CT-guided abscess drainage was necessary to control recurring pain and inflammatory symptoms. No other major or minor complications were noted.

Discussion

This study shows satisfactory pain reduction after MWA in patients with refractory bone or soft tissue tumors. Indeed, immediate pain reduction was obtained in 14/15 patients (93%), with a mean duration of 5.5 months. These results were obtained with a novel minimally invasive procedure under local anesthesia with a low complication rate (0.04%). Moreover, pain alleviation was obtained immediately after procedure (compared with several weeks with radiotherapy). Therefore, MWA ensured significant lasting pain relief, thereby improving end-of-life care in these patients with end-stage neoplasms and intractable pain. In three patients, however, recurrence of pain occurred. In one case, pain recurrence was explained by the occurrence of a local abscess at ablation site. This was the first patient to benefit from MWA, and because there are no guidelines edited by the manufacturer for bone and soft tissue tumor, recommendation for liver ablation was followed: as the lesion was quite large (12×7 cm), MWA was performed at 130 and 180 W for, respectively, 7 and 4 minutes as recommended by manufacturer. We strongly feel that the occurrence of such a complication might be due to the high-powered long-lasting MWA. Indeed, all of the following ablations were performed with lower power and repeated shorter ablation cycles with no consequence on procedure efficacy. With this technique, no

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024

other abscesses were noted, regardless of lesion site (bone or soft tissue, deep or superficial).

Indeed, one of the well-known advantages of MWA (as opposed to RF ablation [RFA]) is the potential to produce faster heating over a larger volume of tissue [14]. This was clearly shown in our study, as the mean ablation time was 4.09 minutes for a mean size tumor of 47 mm. This appears to be faster than other previously reported percutaneous ablation techniques [15,16].

To date, MWA has been described in the management of liver [17–20], kidney [21,22], lung [11,23], thyroid [13], lung [11], and adrenal neoplasms [24]. The use of MWA in bone and soft tissue lesion is not well described, and only a few cases have been described in the literature [19,25–27]. Therefore, our study is the largest reported in the literature on MWA of bone and soft tissue tumors. Moreover, no MWAs of spine lesions have been previously reported. Indeed, management of osseous metastases usually involves radiotherapy, which remains the gold standard treatment [28,29]. However, maximal benefit of radiotherapy is obtained in 5–20 weeks after completion of treatment. This delayed analgesic effect is not satisfactory in these patients suffering from refractory pain with a short life expectancy. Eventhough a previous study by Dennis et al. [30] showed the interest of performing radiotherapy in patients suffering from painful bone neoplasms with limited life expectancy, pain relief obtained with percutaneous MWA is immediate and therefore appears better suited in patients with end-stage neoplasms in which bone pain palliation is the priority. Therefore, minimally invasive percutaneous treatments such as verterbroplasty, RF, combined RF and vertebroplasty, and cryoblation [16] have emerged with satisfactory results in this last decade for the management of painful bone neoplasms. These treatments present a rapid onset of effect with low morbidity rates and are therefore more and more performed in the palliative management of bone metastases. The results of our study showed that MWA appears to be as effective as other percutaneous thermal ablation procedures allowing immediate satisfactory safe pain alleviation.

MWA seems to present some advantages over other thermal ablation techniques, especially RFA. First, because MWA uses electromagnetic waves to produce fast, high tissue-heating effects, it results in a much larger zone of active heating less sensitive to heat-sink effect compared with RFA. Second, MWA appears to be more effective than RFA in high-impedance tissue such as lung or bone tissue [14,31]. This is particularly the case in osteosclerotic lesions, as it has been reported that RFA may not be as effective in sclerotic lesion compared with lytic lesions [16,32]. Some authors reported modifications in RF heat effect of osteoclerotic lesions, with potential severe complications such as severe skin burn and myelopathy [33]. Third, the use of a MWA device is quite simple; it does not require grounding pads (as is the case for monopolar RFA) or other cumbersome accessories (as is the case with cryotherapy). Finally, as was performed in three patients in our cohort, the use of MWA does not prevent from the adjunction of cement in weight-bearing bone lesions, as opposed to cryotherapy that requires 1–24 hours for the iceball to melt.

However, the ability to rapidly deliver high amounts of power with large ablation zones may in fact be a disadvantage when applied to bone and soft tissue lesions (especially subcutaneous and spine lesions) with surrounding overheating possibly leading to severe complications. In order to prevent these complications, we strongly advocate the use of a sterile glove filled with ice cold water positioned at skin entry point in order to avoid severe skin burn in case of lesions located less than 3 cm from skin. Moreover, our experience shows that MWA can be delivered through safe repeated short ablation cycles in order to control the diffusion of the heating zone, without diminishing the effectiveness of MWA. This method should particularly be used in lesions close to vital structures, such as spinal lesions in order to avoid medullary lesions. Some authors have reported the use of a thermocouple to monitor real-time spinal temperature [34]. This device was not used in our study for the three spinal lesions, as the use of local anesthesia along with nitrous oxide ventilation allows real time clinical monitoring and may also help avoid these potential complications.

Limitations of our study are those inherent to small study samples and retrospective studies. Moreover, location of treated lesions are quite heterogeneous, and therefore, multivariate analysis could not be performed. The use of intratumoral block may have influenced immediate postprocedural pain. This is also the case in patients who benefitted from adjunct cemetoplasty. Therefore, immediate pain evaluation may not solely reflect efficacy of MWA alone in these patients. Finally, this study does not constitute a comparative study (with other thermal ablation techniques, i.e. RFA).

Despite these limitations, MWA appears to be a feasible, safe, and effective treatment of painful refractory bone and soft tissue tumors. Well-known advantages of MWA such as its independence to tissue conduction, higher operating temperatures, and lower sensitivity to heat-sink effect maintains a high effectiveness in high-impedance tissues. Thus, it appears to be particularly indicated in bone lesions. It may therefore be considered as a potential alternative percutaneous technique in the management of bone and soft tissue lesions. However, this powerful tool should be used with precaution when lesions are located near vital structures or in proximity to the skin. The use of multiple, short, relatively low-powered heating cycles, especially in cases of small lesions, along with regular intraprocedural clinical examination may help reduce the risk of possible occurring side effects.

References

1 Husband DJ. Malignant spinal cord compression: Prospective study of delays in referral and treatment. BMJ 1998;317(7150):18–21. [Research Support, Non-U.S. Government].

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024

2 Dorrepaal KL, Aaronson NK, van Dam FS. Pain experience and pain management among hospitalized cancer patients. A clinical study. Cancer 1989;63(3): 593–8. [Research Support, Non-U.S. Gov't].

3 Smith HS. Painful osseous metastases. Pain Physician 2011;14(4):E373–403. [Review].

4 Raphael J, Hester J, Ahmedzai S, et al. Cancer pain: Part 2: Physical, interventional and complimentary therapies; management in the community; acute, treatment-related and complex cancer pain: A perspective from the British Pain Society endorsed by the UK Association of Palliative Medicine and the Royal College of General Practitioners. Pain Med 2010;11(6):872–96. [Consensus Development Conference].

5 Dupuy DE, Liu D, Hartfeil D, et al. Percutaneous radiofrequency ablation of painful osseous metastases: A multicenter American College of Radiology Imaging Network trial. Cancer 2010;116(4):989–97. [Clinical Trial Multicenter Study Research Support, N.I.H., Extramural].

6 Hoffmann RT, Jakobs TF, Trumm C, et al. Radiofrequency ablation in combination with osteoplasty in the treatment of painful metastatic bone disease. J Vasc Interv Radiol 2008;19(3):419–25.

7 Toyota N, Naito A, Kakizawa H, et al. Radiofrequency ablation therapy combined with cementoplasty for painful bone metastases: Initial experience. Cardiovasc Intervent Radiol 2005;28(5):578–83.

8 Callstrom MR, Atwell TD, Charboneau JW, et al. Painful metastases involving bone: Percutaneous image-guided cryoablation—Prospective trial interim analysis. Radiology 2006;241(2):572–80. [Research Support, Non-U.S. Gov't].

9 Qian GJ, Wang N, Shen Q, et al. Efficacy of microwave versus radiofrequency ablation for treatment of small hepatocellular carcinoma: Experimental and clinical studies. Eur Radiol 2012;22(9):1983–90. [Research Support, Non-U.S. Gov't].

10 Lloyd DM, Lau KN, Welsh F, et al. International multicentre prospective study on microwave ablation of liver tumours: Preliminary results. HPB (Oxford) 2011;13(8):579–85. [Multicenter Study].

11 Vogl TJ, Naguib NN, Gruber-Rouh T, et al. Microwave ablation therapy: Clinical utility in treatment of pulmonary metastases. Radiology 2011;261(2):643–51.

12 Yu J, Liang P, Yu XL, et al. US-guided percutaneous microwave ablation of renal cell carcinoma: Intermediate-term results. Radiology 2012;263(3): 900–8. [Research Support, Non-U.S. Gov't].

13 Yue W, Wang S, Wang B, et al. Ultrasound guided percutaneous microwave ablation of benign thyroid nodules: Safety and imaging follow-up in 222 patients. Eur J Radiol 2013 Jan;82(1):e11–6.

14 Lubner MG, Brace CL, Hinshaw JL, Lee FT Jr. Microwave tumor ablation: Mechanism of action, clinical results, and devices. J Vasc Interv Radiol 2010;21(8 suppl):S192–203. [Review].

15 Thacker PG, Callstrom MR, Curry TB, et al. Palliation of painful metastatic disease involving bone with imaging-guided treatment: Comparison of patients' immediate response to radiofrequency ablation and cryoablation. AJR Am J Roentgenol 2011;197(2): 510–5. [Comparative Study].

16 Rosenthal D, Callstrom MR. Critical review and state of the art in interventional oncology: Benign and metastatic disease involving bone. Radiology 2012;262(3): 765–80. [Review].

17 Lu MD, Chen JW, Xie XY, et al. Hepatocellular carcinoma: US-guided percutaneous microwave coagulation therapy. Radiology 2001;221(1):167–72.

18 Dong B, Liang P, Yu X, et al. Percutaneous sonographically guided microwave coagulation therapy for hepatocellular carcinoma: Results in 234 patients. AJR Am J Roentgenol 2003;180(6):1547–55. [Evaluation Studies Research Support, Non-U.S. Gov't].

19 Simon CJ, Dupuy DE, Mayo-Smith WW. Microwave ablation: Principles and applications. Radiographics 2005;25(suppl 1):S69–83. [Research Support, Non-U.S. Gov't Review].

20 Brace CL, Laeseke PF, Sampson LA, et al. Microwave ablation with a single small-gauge triaxial antenna: In vivo porcine liver model. Radiology 2007;242(2):435–40. [Research Support, N.I.H., Extramural].

21 Laeseke PF, Lee FT Jr, Sampson LA, van der Weide DW, Brace CL. Microwave ablation versus radiofrequency ablation in the kidney: High-power triaxial antennas create larger ablation zones than similarly sized internally cooled electrodes. J Vasc Interv Radiol 2009;20(9):1224–9. [Comparative Study Research Support, N.I.H., Extramural].

22 Clark PE, Woodruff RD, Zagoria RJ, Hall MC. Microwave ablation of renal parenchymal tumors before nephrectomy: Phase I study. AJR Am J Roentgenol 2007;188(5):1212–4. [Clinical Trial, Phase I].

23 Lu Q, Cao W, Huang L, et al. CT-guided percutaneous microwave ablation of pulmonary malignancies: Results in 69 cases. World J Surg Oncol 2012; 10(1):80.

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024

24 Li X, Fan W, Zhang L, et al. CT-guided percutaneous microwave ablation of adrenal malignant carcinoma: Preliminary results. Cancer 2011;117(22):5182–8. [Evaluation Studies].

25 Fan QY, Ma BA, Zhou Y, Zhang MH, Hao XB. Bone tumors of the extremities or pelvis treated by microwave-induced hyperthermia. Clin Orthop Relat Res 2003 Jan;(406):165–75.

26 Carrafiello G, Lagana D, Pellegrino C, et al. Percutaneous imaging-guided ablation therapies in the treatment of symptomatic bone metastases: Preliminary experience. Radiol Med 2009;114(4):608–25.

27 Simon CJ, Dupuy DE. Percutaneous minimally invasive therapies in the treatment of bone tumors: Thermal ablation. Semin Musculoskelet Radiol 2006;10(2):137–44. [Review].

28 Gilbert HA, Kagan AR, Nussbaum H, et al. Evaluation of radiation therapy for bone metastases: Pain relief and quality of life. AJR Am J Roentgenol 1977;129(6): 1095–6.

29 Hoskin PJ. Palliation of bone metastases. Eur J Cancer 1991;27(8):950–1.

30 Dennis K, Wong K, Zhang L, et al. Palliative radiotherapy for bone metastases in the last 3 months of life: Worthwhile or futile? Clin Oncol (R Coll Radiol) 2011;23(10):709–15.

31 Brace CL, Laeseke PF, Sampson LA, et al. Microwave ablation with multiple simultaneously powered small-gauge triaxial antennas: Results from an in vivo swine liver model. Radiology 2007;244(1):151–6.

32 Goetz MP, Callstrom MR, Charboneau JW, et al. Percutaneous image-guided radiofrequency ablation of painful metastases involving bone: A multicenter study. J Clin Oncol 2004;22(2):300–6. [Clinical Trial Multicenter Study Research Support, Non-U.S. Gov't].

33 Clarencon F, Jean B, Pham HP, et al. Value of percutaneous radiofrequency ablation with or without percutaneous vertebroplasty for pain relief and functional recovery in painful bone metastases. Skeletal Radiol 2013 Jan;42(1):25–36.

34 Nakatsuka A, Yamakado K, Takaki H, et al. Percutaneous radiofrequency ablation of painful spinal tumors adjacent to the spinal cord with real-time monitoring of spinal canal temperature: A prospective study. Cardiovasc Intervent Radiol 2009;32(1):70–5.

Downloaded from https://academic.oup.com/painmedicine/article/14/12/1873/1911642 by guest on 23 April 2024