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LETTER TO THE EDITOR

Large nearly spherical ablation zones are achieved with simultaneous multi-antenna microwave ablation applied to treat liver tumours

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Abstract

Aim To investigate the shape and the volume of ablation zones obtained with microwave ablation (MWA) performed with multiple antennas in liver tumours.

Materials and methods Tumour volume, number of antennas, size (long diameter (Dl), along the antenna axis; short diameter (Ds), perpendicular to the antenna axis; vertical diameter (Dv), vertical to both Dl and Ds) and shape (roundness index (RI); 1 corresponds to a sphere) of the ablation zone, ablation volume, and complications were evaluated.

Results Mean Dl, Ds, and Dv were 4.7 ± 1.4 cm, 3.9 ± 1.4 cm, and 3.8 ± 1.0 cm, respectively. Mean RIs (Ds/Dl, Dv/Dl, and Dv/Ds) were 0.83 ± 0.13, 0.83 ± 0.17, and 1.02 ± 0.23, respectively, without any difference between the mean RI obtained with the double (0.84 ± 0.01) and that with the triple-antenna (0.93 ± 0.13) approach ($p = 0.25$). Mean ablation volume was 41 ± 32 cm^3 (vs. mean tumour volume 13 ± 10 cm^3; range 1–40; $p < 0.001$). No complications were noted.

Conclusions Simultaneous multi-antenna MWA of liver tumours results in large nearly spherical ablation zones.

Key Points

- *Simultaneous multi-antenna microwave ablation of liver tumours results in nearly spherical ablation zones.*
- *The multi-antenna approach generates oversized ablation volumes compared with the target tumour volume.*
- *The multi-antenna approach is safe.*

Keywords Liver · Neoplasms · Microwaves

Abbreviations

Dl	Long diameter
Ds	Short diameter
Dv	Vertical diameter
MWA	Microwave ablation
LTC	Local tumour control
RI	Roundness index

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Introduction

Microwave ablation (MWA) generates relatively large necrosis [1]. To further increase the ablation zone, sequential MWA or simultaneous applications of multiple antennas have been proposed [2–4]. Recent laboratory studies performed in ex vivo and in vivo animal liver models have highlighted that the latter approach results in larger ablation zones compared with the former [2, 4]. Nevertheless, there is a substantial lack of data about this new treatment modality in patients presenting with liver tumours.

The aim of our study was to retrospectively investigate the shape and the volume of ablation zones obtained with MWA performed with multiple antennas in liver tumours.

Materials and methods

This study was approved by the institutional review board with a waiver of written informed consent. Liver tumours treated with the multi-antenna approach from December 2017 to February 2019 were included.

Percutaneous MWA

All procedures were performed under general anaesthesia using US/CT-guidance. Different 15-17G antennas were used with a commercially available MWA system (NEUWAVE™; Johnson & Johnson). According to authors' experience, in the perspective of obtaining large safety margins, when the largest axis of the tumour measured ≥ 30 mm, a triple-antenna approach was used; for tumours with the largest axis between 2 and 3 cm, a double-antenna approach was used.

MWA was performed by simultaneous activation of all the antennas (heating cycle, 65 W; 10 min). Antennas were spaced 2 cm apart (Fig. 1). Hydro-dissection was utilised to protect nearby non-target structures if needed.

Data collection

The following data were collected: patient characteristics (age, sex); tumour characteristics (histology, location in liver segments, proximity to large (> 3 mm) vessels, maximum diameter on multiplanar pre-operative imaging, volume); procedural details (number of antennas, number of heating cycles, number of times antennas were repositioned, additional hydro-dissection, size, shape, and volume of the ablation zone, complications); and local tumour control (LTC).

Tumour volume was calculated on contrast-enhanced pre-operative imaging by using dedicated segmentation software (Centricity™ Universal Viewer; GE Healthcare).

The size of the ablation zone was obtained by measuring the long diameter (Dl, along the antenna axis), the short diameter (Ds, perpendicular to the antenna axis), and the vertical diameter (Dv, vertical to Dl and Ds) on immediate post-ablation contrast-enhanced CT. The shape of the ablation zone was evaluated through roundness indexes (RIs) by calculating the following ratios: Ds/Dl, Dv/Dl, and Dv/Ds (i.e. values close to 1 were considered spherical). The volume of the ablation zone was calculated on immediate post-ablation contrast-enhanced CT through the same aforementioned segmentation method. LTC was evaluated on follow-up contrast-enhanced CT or MRI.

Statistical analysis

The Wilcoxon and Fisher tests were used. Significance levels were set at 0.05.

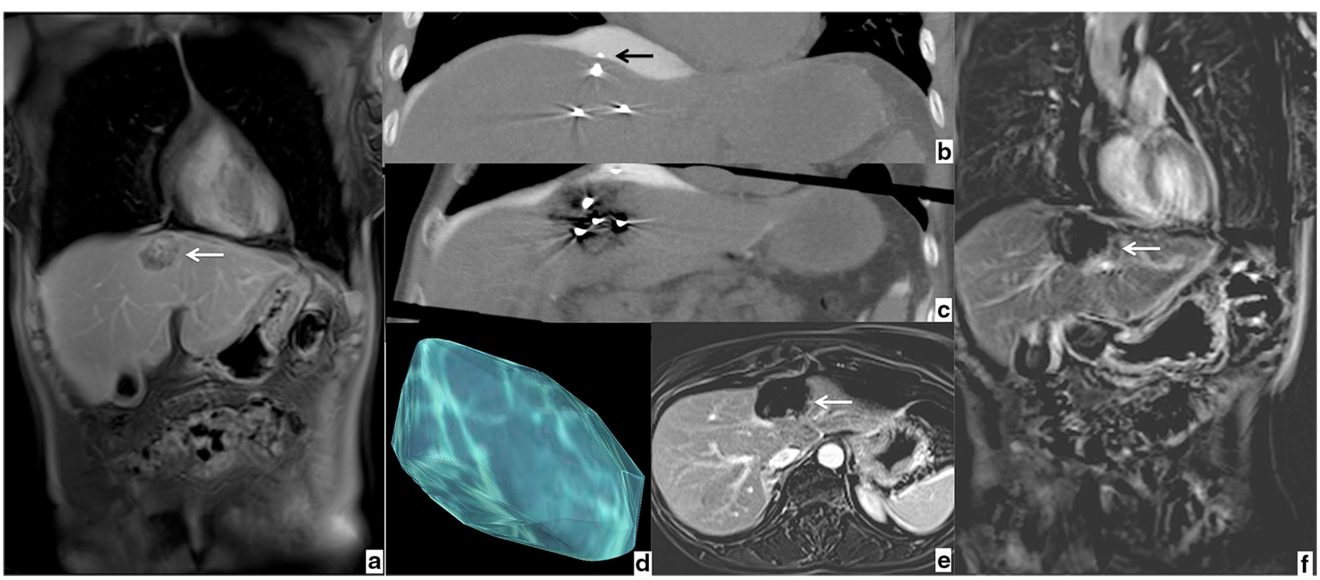

Fig. 1 A 58-year-old female patient presenting with a single liver melanoma metastasis. Coronal (**a**) contrast-enhanced T1-weighted MR image showing the tumour of the IV liver segment (arrow; 3 × 4 ×3 cm; volume 19.7 cm^3). A triple-antenna MWA was performed (**b**); antennas were deployed with 2-cm spacing and a triangular configuration; hydro-dissection (arrow) was performed to protect the diaphragm and the heart. Coronal CT image obtained just after MWA shows the necrotic area filled with gas locules (**c**). The RIs of the ablation area were Ds/Dl 0.85, Dv/Dl 1.12, Dv/Ds 1.3, thus being consistent with an oval shape (**d**) tending to roundness; the relative computed ablation volume was 85 cm^3. Axial (**e**) and coronal (**f**) contrast-enhanced T1 MR images showing the necrotic area (arrows) without recurring disease at 8-month follow-up. MWA, microwave ablation; Dl, long diameter; Ds, short diameter; Dv, vertical diameter

Table 1 Patient and tumour characteristics

Patient	Tumour case	Age	Sex	Type of tumour	Maximal 3D tumour diameters (cm)	Tumour volume (cm^3)	Liver segment
1	1	65	F	Ovarian tumour	3.4 × 3.1 × 3.1	16	V
2	2	50	F	Colon cancer	2.8 × 2.6 × 3.4	12	VIII
3	3	73	F	Breast cancer	4.1 × 3.3 × 2.6	18	VIII
4	4	58	F	Melanoma	3.0 × 4.0 × 3.0	18	IVa
5	5	74	M	HCC	3.0 × 2.8 × 2.8	12	III
	6				2.1 × 2.3 × 2.1	5	IVA
6	7	75	F	HCC	2.6 × 3.4 × 3.0	13	II
7	8	74	M	Colon cancer	1.6 × 1.2 × 1.2	1	VIII
	9				3.0 × 2.4 × 3.0	11	VII
	10				1.9 × 1.7 × 1.6	3	VI
	11				3 × 2.9 × 2.8	12	VII
8	12	61	F	Pulmonary neuroendocrine tumour	1.6 × 2.0 × 1.7	3	VIII
	13				2.8 × 2.4 × 2.8	9	VIII
9	14	70	F	HCC	4.4 × 4.2 × 4.3	40	VII
10	15	76	F	HCC	3.2 × 2.8 × 3.1	14	VIII

HCC, hepatocellular carcinoma

Results

Baseline characteristics

Patient and tumour characteristics are summarised in Table 1. Fifteen tumours were treated (mean maximal diameter 3.0 ± 0.8 cm; range 1.6–4.4; mean volume 12 ± 9 cm^3; range 1–40) in 11 sessions. Six tumours (40%) were close to large vessels. Nine tumours (60%) were treated with 3 antennas and 6 (40%) with 2. Hydro-dissection was used in 8 sessions (72.7%). No complications were noted.

Ablation area and local tumour control analysis

The results of MWA are summarised in Tables 2 and 3. After excluding tumours treated with multiple heating cycles or antenna repositioning (tumour n. 1, 3, and 12) and tumours without immediate post-ablation contrast-enhanced CT (tumour n. 6), the mean calculated diameters of the ablation zone were Dl 4.7 ± 1.4 (range 2.1–6.3); Ds 3.9 ± 1.4 (range 1.6–6.7); and Dv 3.8 ± 1.0 (range 1.8–5.5). Mean RIs were Ds/Dl 0.83 ± 0.13 (range 0.59–1.08); Dv/Dl 0.83 ± 0.17 (range 0.56–1.12); and Dv/Ds 1.02 ± 0.23 (range 0.70–1.48). Overall, the mean RI did not differ between the double- and the triple-antenna approach (0.84 ± 0.01; range 0.70–0.91; vs 0.93 ± 0.13; range 0.70–1.1; $p = 0.25$).

The mean ablation volume was 41 ± 32 cm^3 (range 4–95), significantly larger than the mean tumour volume (13 ± 10 cm^3; range 1–40; $p < 0.001$).

At imaging follow-up (mean 4 ± 3 months; range 1–9) available in 13/15 tumours (87%), LTC was 92% (i.e. a 7-mm residual tumour was noted on the 4-month MRI in one metastasis close to the inferior cava vein).

Discussion

The mean size of the diameters of the ablation zone was almost 4 cm, which is approximately 1 cm larger than the mean maximal diameter of treated tumours, thus indicating a satisfactory oversizing of the ablation area. This impression was further confirmed by the volumetric analysis, which proved that the mean ablation volume was threefold larger than the mean tumour volume. Moreover, although not statistically significant probably due to the small sample size, when 3 antennas were used, the mean ablation volume was nearly threefold larger than that achieved with 2 antennas, which is in line with data obtained from pre-clinical experiences [2, 5].

In our series, the RI was equal to 1 in only one axis, thus implying a more oval-shaped ablation zone. Nevertheless, the other two RIs were 0.83, thus suggesting a tendency towards roundness. Nevertheless, a more pronounced roundness was noted with the triple-antenna approach (0.93) rather than with the double one (0.84), which is also reflected by more the prominent increase in size of Dv and Ds with the former approach compared with the latter.

In Zhang et al [4], 4 activated antennas were used simultaneously and 4 cm was the best-suggested spacing interval between antennas. Nevertheless, their study was conducted with an ex vivo model, thus neglecting the “heat-sink” effect; which is not the case in vivo, where a more fitted approach is probably more adapted in accordance with Harari et al [2] and the present experience of ours.

Table 2 Results dealing with the ablation zone (i.e. size, volume, and shape), and evolution of the treated site

Tumour case	N. antenna per tumour	Ablation zone			Ablation volume (cm^3)	Ds/Dl	Dv/Dl	Dv/Ds	Local tumour control	Follow-up duration (months)
		Dl	Ds	Dv						
1+	3	5	3.8	4.2	60	0.76	0.84	1.11	Yes	9
2	3	4.2	4.1	4.0	39	0.98	0.95	0.98	No	4
3+	3	7.8	4.5	6.1	134	0.58	0.78	1.36	Yes	6
4	3	4.9	4.2	5.5	85	0.86	1.12	1.31	Yes	8
5	2	4.7	4.0	3.5	26	0.85	0.74	0.88	N/A	N/A
6**+	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	3	6.2	4.9	3.6	43	0.79	0.58	0.73	Yes	1
8	2	3.5	2.8	3	10	0.80	0.86	1.07	Yes	2
9	3	3.1	2.1	3.1	16	0.68	1.00	1.48	Yes	2
10	2	2.1	1.6	1.8	4	0.76	0.86	1.13	Yes	2
11	3	4.5	3.9	4	18	0.87	0.89	1.03	Yes	2
12+	2	3.7	3.2	4.1	18	0.86	1.11	1.28	Yes	2
13	3	5.7	4.9	4.8	81	0.86	0.84	0.98	Yes	2
14	3	6.2	6.7	4.7	95	1.08	0.76	0.70	Yes	4
15	2	6.3	3.7	3.5	34	0.59	0.56	0.95	Yes	2

Dl, longitudinal diameter; *Ds*, short diameter; *Dv*, vertical diameter; *N/A*, not available

**Missing data regarding immediate post-ablation contrast-enhanced CT

+ Excluded from the analysis of the shape and volume of the ablation zone

Vogl et al [6] have recently proved that spherical ablations result in larger ablative margins. For this reason, new MWA technologies are designed to achieve such ablation geometry. In this perspective, results in vivo and ex vivo are limited to single-antenna approaches that seem effective for tumours sized less than 3 cm [1, 6–8] (which was not much reflected in our experience, and consequently a multi-antenna approach was started in our institution also for 2–3-cm-sized tumours). On the contrary, for tumours larger than 3 cm, the synchronous multiple-antenna approach providing larger ablation volumes seems more adapted. However, in vivo experience with such approach remains limited. Ziemlewicz et al [9] treated 107 hepatocellular carcinomas with a single-, double-, or triple-antenna approach. They did not stratify their results according to the number of antennas and reported a 1-month LTC 91.8% for tumours ≤ 3 cm; 100% for tumours sized 3.1–4.0 cm; and 50% for tumours > 4 cm.

The large ablation zones achieved in our experience were not obtained at the cost of an increased morbidity. Nevertheless, extensive hydro-dissection was used as suggested in the literature [10].

Limitations of our study deal with the retrospective nature and the small sample size.

In conclusion, simultaneous multi-antenna MWA applied to treat liver tumours results in large, nearly spherical ablation volumes.

Table 3 Results dealing with ablation zone size, shape, and volume according to the number of antennas deployed

	2 antennas (n = 4)	3 antennas (n = 7)	p value
Mean tumour volume (cm^3)	8 ± 7 (1–14)	16 ± 11 (9–40)	0.29
Mean Dl	4.2 ± 1.8 (2.1–6.3)	5.0 ± 1.1 (3.1–6.2)	0.64
Mean Ds	3.0 ± 1.1 (1.6–4.0)	4.4 ± 1.4 (2.1–6.7)	0.07
Mean Dv	3.0 ± 0.8 (1.8–3.5)	4.2 ± 0.8 (3.1–5.5)	0.03
Mean RI	0.84 ± 0.01 (0.70–0.91)	0.93 ± 0.13; (0.70–1.1)	0.25
Mean ablation volume (cm^3)	19 ± 14 (4–34)	54 ± 33 (16–95)	0.07

Dl, longitudinal diameter; *Ds*, short diameter; *Dv*, vertical diameter

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Compliance with ethical standards

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Statistics and biometry No complex statistical methods were necessary for this paper.

Informed consent Written informed consent was waived by the Institutional Review Board.

Ethical approval Institutional Review Board approval was obtained.

Methodology
- retrospective
- observational
- performed at one institution

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