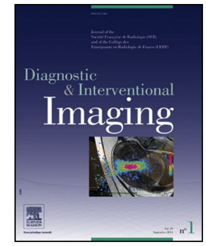
+Model
DIII-981; No. of Pages 6
ARTICLE IN PRESS

Diagnostic and Interventional Imaging (2017) **xxx**, xxx—xxx



ORIGINAL ARTICLE /*Interventional imaging*

In vivo percutaneous microwave ablation in kidneys: Correlation with *ex vivo* data and ablation work

C. Marcelin [a,*], J. Leiner [b], S. Nasri [b], F. Petitpierre [a], Y. Le Bras [a], M. Yacoub [b], N. Grenier [a], J.C. Bernhard [c], F. Cornelis [a,d]

[a] *Service d'imagerie diagnostique et thérapeutique de l'adulte, hôpital Pellegrin, CHU de Bordeaux, place Amélie-Raba-Léon, 33076 Bordeaux, France*
[b] *Service d'anatomopathologie, hôpital Pellegrin, CHU de Bordeaux, place Amélie-Raba-Léon, 33076 Bordeaux, France*
[c] *Service de chirurgie urologique, hôpital Pellegrin, CHU de Bordeaux, place Amélie-Raba-Léon, 33076 Bordeaux, France*
[d] *Service de radiologie, hôpital Tenon, AP—HP, 4, rue de la Chine, 75020 Paris, France*

KEYWORDS
Microwave ablation;
Kidneys;
Experimental;
Animal model;
In vivo

Abstract
Purpose: To compare diameters of in vivo microwave ablation (MWA) performed in swine kidneys with *ex vivo* diameters, and to correlate with ablation work (AW), a new metric reflecting total energy delivered.
Material and methods: Eighteen in vivo MWA were performed in 6 swine kidneys successively using one or two antennas (MicroThermX®). Ablation consisted in delivering power (45—120 W) for 5—15 minutes. Ex vivo diameters were provided by the vendors and obtained on bovine liver tissue. AW was defined as the sum of (power)*(time)*(number of antennas) for all phases of an ablation (in kJoules). Kidneys were removed laparoscopically immediately after ablation. After sacrifice, ablations zones were evaluated macroscopically, and maximum diameters of the zones were recorded. Wilcoxon sum rank test and Pearson's correlation were used for comparisons.
Results: For a single antenna ($n = 12$), the in vivo diameters ranged from 12 to 35 mm, and 15—49 mm for 2 antennas ($n = 6$). The in vivo diameters remained shorter than *ex vivo* diameters by 8.6% ± 30.1 on 1 antenna and 11.7% ± 26.5 on 2 antennas ($P = 0.31$ and 0.44, respectively). AW

* Corresponding author.
E-mail address: clement.marcelin@gmail.com (C. Marcelin).

http://dx.doi.org/10.1016/j.diii.2017.09.002

ranged from 13.5 to 108 kJ. Diameters increased linearly with AW both with 1 and 2 antennas, but only moderate correlations were observed (r = 0.43 [95% confidence interval: −0.19; 0.81], P = 0.16; and 0.57 [−0.44; 0.95], P = 0.24, respectively).
Conclusion: Although diameters after in vivo renal MWA increased linearly with AW, the moderate correlation and wide standard deviations observed may justify a careful imaging monitoring during treatment delivery and settings adaptation, if needed, for optimal ablation.

Microwave ablation (MWA) has recently been proposed in the kidneys for the treatment of T1a renal tumors (< 4 cm) [1,2]. By allowing oscillation of polar molecules such as water-producing frictional heating, MWA has several advantages compared to radiofrequency ablation (RFA) [3]. Faster generation of hotter temperatures, decreased susceptibility to heat sink effects, and improved energy penetration in charred/desiccated tissue are observed, leading to potentially larger ablation zones [1,3].

Although the volume of MWA depends both on the length and the diameter of ablation, the length remains often substantially greater than the transverse dimension after MWA [4]. Length is impacted by many factors, including antenna design and radiating segment, frequency/wavelength, ablation time, and applied power, but now appears to be predictable and more spherical and thus controllable, resulting in a lower rate of major complications than before [5—8]. Many other parameters such as relative permittivity, effective conductivity, water content or perfusion of tissues, may affect the diameter of MWA directly, making this metric less predictable [3]. The applicability of the ex vivo algorithm provided by the vendors or the in vivo references obtained in liver tissues therefore remains unclear for in vivo renal MWA [5,6,9—16].

The purpose of this experimental study on swine kidneys was firstly to compare the diameters of percutaneous MWA obtained in vivo using a single or two antennas with the ex vivo diameters provided by the vendors for renal ablation, and obtained on bovine liver tissue, and secondly to establish correlations with ablation work (AW), a new metric reflecting the total energy delivered. AW reflects the total amount of work as a summation of applicator power and time product over different phases of the ablation, allowing a comparison of ablation outcomes using different settings or several devices [8,17].

Materials and methods

Animal model and microwave ablations

Animal procedures were approved by our institutional animal care and use in research committee and were compliant with regulatory guidelines [18]. A total of 18 ablations were performed in the 6 kidneys of 3 domestic swine (weight 45—55 kg), 3 ablations per kidney. Animals were initially sedated with 10 ml intramuscular Ketamine (Ketamine 1000, Virbac, France), and 1 ml intramuscular Acepromazine (Calmivet, Vetoquinol, France). Endotracheal intubation was facilitated by an injection of 4 ml pentobarbital (Exagon, Axiance, France). Intravenous injections of pentobarbital, morphine, and acepromazine were used for the duration of the procedure. Cardiac monitoring was performed.

MWA were performed using up to two 14G water-circulating cooling microwave antennas connected to the 915 MHz MicroThermX® microwave system (Terumo, Tokyo, Japan). Antennas had short (2 cm) or long (4.1 cm) active zones at the tip. This technology delivers microwave energy for ablation using synchronous wave alignment technology allowing non-parallel placement and avoiding skipping when using multiple antennas. Microwave antennas were placed percutaneously on the upper-, mid- and inferior poles of each kidney under ultrasound guidance (Fig. 1A and B). When 2 antennas were used, a distance of 15 mm was obtained to ensure overlapping of the ablation zones as recommended by the vendor. Time (s) and power (W) settings were recorded continuously. Bilateral en bloc nephrectomy was performed laparoscopically immediately after the MWA. Euthanasia was performed with an intravenous injection of phenobarbital (25 ml Dolethal® 180 mg, Vetoquinol, France) immediately thereafter according to regulatory procedures.

Ablation zone evaluation

The kidneys were set in formaldehyde and sent for immediate macroscopic and microscopic analysis. The ablation zones were measured on the anatomical resection pieces. Sections were made every 5 mm perpendicular to the axis of the antenna. The tissue sections were photographed and digitized. The dimensions were measured on each section: maximum diameter, maximum length and thickness.

Statistical analysis

The ex vivo diameters obtained in ex vivo bovine liver tissue were provided by BSD Medical Corporation distributed in Europe by Terumo Europe N.V. [19]. The maximum diameters obtained in vivo were compared with ex vivo diameters using Wilcoxon's Matched Pairs Signed-Ranks test. AW was defined

Please cite this article in press as: Marcelin C, et al. In vivo percutaneous microwave ablation in kidneys: Correlation with *ex vivo* data and ablation work. Diagnostic and Interventional Imaging (2017), http://dx.doi.org/10.1016/j.diii.2017.09.002