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REVIEW / *Interventional imaging*

Microwave ablation of renal tumors: A narrative review of technical considerations and clinical results

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Abstract
Purpose: The purpose of this review was to identify the specific technical considerations to adequately perform microwave ablations (MWA) of renal tumors and analyze the currently available clinical results.
Methods: Using *Medline*, a systematic review was performed including articles published between January 2000 and September 2016. English language original articles, reviews and editorials were selected based on their clinical relevance.
Results: MWA has several theoretical advantages over radiofrequency ablation in consistently providing higher intratumoral temperatures. MWA is less dependent of electrical conductivities of tissues and the delivered energy is less limited by desiccation of heated tissues. While there are insufficient data, especially because of a lack of studies with mid- to long-term follow-up, to determine the oncologic effectiveness of MWA, this technique appears safe and effective for the ablation of T1 renal tumors. There is evidence for using mid-level settings based on experimental and clinical data. Power set at 50—65 W for 5—15 min appears adequate in kidney but close clinical and imaging follow-up have to be performed.
Conclusion: Renal MWA offers theoretical advantages by comparison with other available techniques to treat renal tumors. However, MWA suffers of less cumulative data compared to radiofrequency ablation or cryoablation. Moreover, microwaves still require further studies to identify the optimal tumor characteristics and device settings leading to predictable ablation.

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The early detection of small renal tumors, often in a non-metastatic stage, has considerably modified the management of renal cell carcinomas (RCC) [1—3]. The development of nephron-sparing techniques and ablative therapies are now the standard option for the curative treatment of T1 RCC (< 7 cm) [4]. For patients with small renal cancers who are not amenable to surgery, because of advanced physiological age, comorbidities, or already precarious renal function, the percutaneous approach using thermal ablation is gradually predominating [5]. As conventional ablative techniques such as radiofrequency ablation (RFA) or cryoablation may present limitations in terms of efficacy for tumor greater than 3—4 cm [6,7], new technologies such as microwave ablations (MWA) appear particularly appealing in this context [8,9].

MWA has several theoretical advantages over RFA because it consistently provides higher intratumoral temperatures, is less dependent on electrical conductivities of tissue and because the energy delivery is less limited by the exponential rising electrical impedances of heated tissue [10]. However, MWA suffers of less cumulative data in terms of results by comparison with RFA or cryoablation. Evidence for long-term oncologic efficacy is still lacking.

The purpose of this narrative review was to identify the specific technical considerations to adequately perform MWA of renal tumors and analyze the currently available clinical results.

Evidence acquisition

A systematic Medline/PubMed© literature search was performed with different combinations of terms as ''MWA,'' ''microwave,'' ''kidney,'' ''renal cell carcinoma,'' ''renal tumor.'' Time period included articles published between January 2000 and September 2016. Original articles, reviews and editorials were selected based on their clinical relevance. Cited references from selected articles were analyzed to find and include significant papers previously excluded from our search, including articles published before 2000.

Microwave technology

Microwaves are electromagnetic radiations with wavelengths ranging from one meter to one millimeter corresponding to frequencies between 300-MHz (100 cm) and 300-GHz (0.1 cm). Differently to RFA, which uses ion flow to produce tissue-heating effects, the oscillation of polar molecules producing frictional heating such as water is obtained by microwave exposure, ultimately generating tissue necrosis within solid tumors. At these frequencies, directional changes of water molecules occur 2—5 billion times per second [11]. Microwaves propagate through many types of tissue, even those with low electrical conductivity, high impedance, or low thermal conductivity [12]. In particular, microwaves can penetrate through the charred or desiccated tissues, which tend to build up around all hyperthermic ablation applicators.

Relative permittivity and effective conductivity are the two most important properties to consider for MWA [13]. Permittivity is a material property that affects the Coulomb force between two point charges in the material. The relative permittivity of a material is its (absolute) permittivity expressed as a ratio relative to the permittivity of vacuum and may be considered as the factor by which the electromagnetic field between the charges is decreased relative to vacuum. It may correspond to how well a material will accept an electric field. Relative permittivity determines the wavelength of an applied field at a given frequency, which impacts how well energy will propagate through the tissue and how the antenna is designed [13]. Higher degrees of permittivity lead to shorter wavelengths. Because permittivity is greater in tumoral tissues than in normal tissues, a better diffusion of microwaves is obtained in tumors [14]. It means that marked differences in permittivity between tumors and surrounding tissue may allow better treatment with MWA.

Effective conductivity corresponds to how well the tissue will absorb microwave energy. High water content increases conductivity but absorbs microwaves [13]. Low water content decreases conductivity while increasing the microwave propagation. In the kidney, the high electrical conductivity of kidney allows faster microwave energy absorption but reduces field penetration. However, heating may increase progressively the propagation of microwaves by producing desiccation of tissue and then reduction of conductivity [13].

However, only few data on temperature-dependent dielectric properties of kidney are available in the frequency range of MWA and for various conditions [15]. Fu et al. studied frequency-dependent dielectric properties of various tissues including normal kidney for a range of temperature and frequency (36—60 °C, 42—468 MHz) [16]. The dielectric constant and the conductivity obtained at the same temperature and frequency ranges were 37.3—169.26 and 0.8061—1.3625 S/m. At 2.45 GHz and 37 °C (1.5 cm wavelength), relative permittivity was estimated at 52.8, effective conductivity at 2.43 S/m [13]. Relative permittivity and conductivity measurements made at 915 MHz and 2.45 GHz during thermal ablation tended to drop quickly in all cases when temperatures reached 100 °C and continued to drop as temperature was maintained and the tissue became more dehydrated [17]. Further studies including evaluation of tumoral tissue are mandatory and may help to better establish the most adequate settings of MWA.

Thermal profile of MWA

Compared to RFA, MWA creates larger ablation zones than does a similarly sized RF applicator for similar application time ex-vivo or in preclinical animal model [10]. Temperatures of 160—180 °C are often observed with MWA and temperature increasing is faster than that observed with RFA [10,13,18]. The energy deposition is therefore higher with MWA, less susceptible to heat-sink effect and thermal diffusion. However, thermal diffusion remains depending of tissue characteristics, which may change substantially during heating [13].

Heat transfer in tissue can be modeled using the so-called bioheat transfer equation [19]. The cumulative equivalent minutes at 43 °C (CEM43) is the accepted metric for

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