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Review

Image guided radiofrequency ablation for small renal masses

Emily F. Kelly, Raymond J. Leveillee*

Department of Urology, Florida Atlantic University, Charles E. Schmidt College of Medicine, Bethesda Health, Boynton Beach, FL, USA

HIGHLIGHTS

- The detection of small renal masses (SRM) has increased due to the increased use of cross-sectional abdominal imaging. Renal parenchyma preservation has become the standard of care.
- Thermal ablation (TA) is discussed and often offered for all patients with SRM as near-equivalent treatment without respect to age or co-morbidities. As provider experience improves and long-term outcome studies become available, TA is becoming increasingly accepted as a potential new standard of care for solid SRM.
- This review will highlight the role of image guided TA. We will discuss radiofrequency ablation (RFA) however, the principles will apply to any TA device. Improvements in image guided hardware/software has improved accuracy of probe placement.

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ABSTRACT

The diagnosis of incidental small renal masses (SRM) has increased during the past two decades secondary to the increased use of various abdominal imaging modalities. In the past decade there has been a shift from radical nephrectomy to nephron sparing surgery techniques where partial nephrectomy has become the standard of care. Thermal ablation (TA) modalities such as freezing or heating delivered percutaneously for the treatment of small renal masses (SRM) is now offered in many Institutions as a treatment option. Clinical guidelines have indicated that TA is appropriate for select patients that are medically high risk or elderly. In our institution and in select centers, TA is discussed and often offered for all patients with SRM as equivalent treatment without respect to age or co-morbidities. As provider experience improves and long-term outcome studies become available, TA is becoming increasingly accepted as a potential new standard of care for solid SRM. This review will highlight the role of image guided radiofrequency ablation (RFA) techniques and their application focusing on the different imaging modalities for RFA application which, most commonly, include percutaneous (Magnetic Resonance Imaging (MRI) and computerized tomographic (CT). Our aim is to summarize those studies along with long term follow up.

1. Introduction

The diagnosis of incidental small renal masses (SRM), most commonly renal cell carcinoma (RCC), has increased during the past two decades due to the increased availability and utilization of imaging [1,2]. SRM encompass clinical stage cT1a <4 cm [3]. In recent years, the standard treatment of SRM has shifted from RN to nephron sparring surgery (NSS) in which PN has become the new standard of care for tumors which do not invade the collecting system [4]. The goal of NSS is to resect/ablate the tumor and small surrounding rim of healthy tissue to ensure negative margins while preserving an optimal amount of renal function [4,5]. NSS options include PN, TA, and non-thermal ablation (irreversible electroporation) where cryoablation (CRY), microwave ablation (MWA), and radiofrequency ablation (RFA) are the most common forms of TA [5]. It is beyond the scope of this review to discuss these alternative options thus we will focus on RFA.

In 2009 the American Urologic Association (AUA) published Clinical Guidelines for treatment of SRM. TA was suggested as a treatment option in patients with T1a tumors and major co-morbidities and/or patients unable to undergo surgery. Additionally, the update suggested TA as an option in healthy patients with T1a/b lesions, as well as patients with major co-morbidities with stage T1b tumors [6,7].

* Corresponding author.
E-mail addresses: rleveillee@bhpgdoc.com, rleveillee@fau.edu (R.J. Leveillee).

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2. Materials and methods

A literature search was conducted, PubMed. The main search term was “radiofrequency ablation” alone and in combination with “renal cancer, CT-guided, MR-guided, and percutaneous-approach.” Selection criteria included a judgment about the novelty and importance of studies and their relevance. Special focus was placed upon technological advances, safety, renal functional preservation, and long-term oncological results.

3. Support/results

Currently the literature suggests that RFA is most successful in SRM <4 cm. Gervais et al. reports a retrospective series of 100 renal tumors treated with RFA. 100% of SRM <3 cm, 92% of 3–5 cm masses, and 25% of masses >5 cm were treated successfully [1,2]. Zagoria et al. demonstrates that with each 1 cm increase in diameter above 3.6 cm the likelihood of recurrence-free survival decreases by a factor of 2.19 and recommends caution when treating tumors >4 cm [8]. Olweny et al. compares the 5 year outcomes for RFA vs PN in T1a treated RCC and reports 97.2% vs 100% ($p = 0.31$) cancer specific survival, 97.2% vs 100% ($p = 0.31$) overall survival, and 91.7 vs 94.6% ($p = 0.96$) local recurrence-free survival [9]. Psutka et al. reports on 185 patients with T1 RCC followed for a mean of 6.43 years. The overall disease free survival rate was 88.6% (92.3% T1a and 76.3% for T1b) and only 13% of patients were retreated for recurrence [10]. Please refer to Table 1 for additional results.

4. Discussion

4.1. Radiofrequency ablation

4.1.1. Principles

The main mechanism of RFA depends primarily on the principle of heat conduction inducing cellular death [4]. Secondary mechanisms include vaporization and coagulative necrosis. Alternating current with a frequency between 375 and 900 KHz is delivered by a generator to an electrode probe which has been placed in the center of the target tissue. Most often these systems are monopolar. The ablation zone of thermal conductivity remains unmodified 1–2 mm from the tip of the needle probe [11]. The resulting coagulation provides an advantage of RFA since no topical hemostatic agents must be utilized post-ablation to control bleeding as has been seen with cryoablation [4].

The effects of RFA induced cellular injury relies on a time-temperature curve where ablations at higher temperatures require less time. Bhowmick et al. describes this phenomenon demonstrating that cellular damage occurs after 60 min at 45 °C, 5 min at 55 °C, or 1 min at 70 °C [5]. As temperature increases, ionic agitation of intracellular molecules develops resulting in frictional heating. Once temperatures reach above 60 °C, the cell loses its intracellular buffering capacity which results in the accumulation of intracellular calcium and eventual cellular death. As local inflammation increases, acidosis occurs and coagulative necrosis results [1,2]. As temperature increases different phases of cellular damage are observed. Coagulation and cellular damage, secondary to protein denaturation, blood coagulation, and irreversible cellular death, results after exposure to temperatures between 50 and 80 °C for seconds to minutes. Vaporization damage resulting in dehydration, vacuole formation, and tissue ablation occurs at temperatures above 100 °C. Lastly, carbonization in the form of melting and charring transpires once temperatures reach between 150 and 300 °C [4]. Carbonization is to be avoided as a zone of extremely high impedance results, thus limiting RF current passage and thermal spread.

The success of RFA depends on a temperature-based algorithm and treatment end points detected by temperature monitors, temperature probes, and impedance probes [12]. We recommend that a temperature goal of at least 60 °C be obtained in order to achieve instantaneous irreversible cell damage by denaturation of

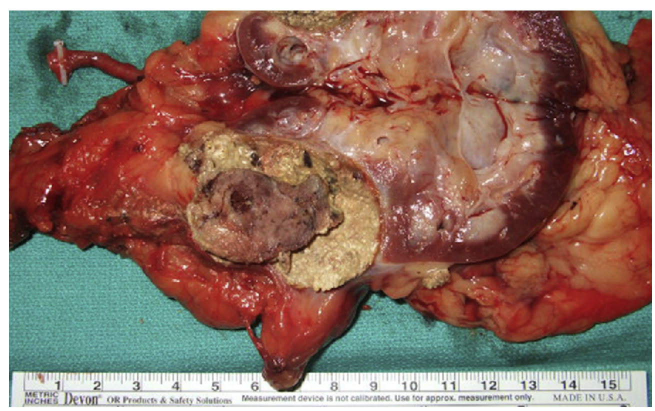

Fig. 1. TA works: Gross image (confirmed histologically) demonstrating complete destruction of 4.7 cm left renal clear cell carcinoma via coagulative necrosis. Kidney removed at 12 months follow-up after being treated successfully by laparoscopic RFA, Cool-tip® (Valley Lab, Boulder, CO, USA) under laparoscopic US Image guidance.

Table 1
Previous series of “long term” follow-up after primary RFA.

	Ma et al.[33]	Lorber et al.[34]	Kim et al.[35]	Zagoria et al.[8]	Tracy et al.[36]	Balageas et al.[37]	Ramirez et al.[38]
Pt number	52	50	47	41	208	62	79
Tumor number	58	53	48	48	243	71	111
Tumor size	2.2	2.3 (0.3–4.0)	2.3 (1.0–3.0)	2.6 (0.7–8.2)	2.4	2.3	2.2 (0.9–4.2)
Approach: Lap	24	24	12	0	68	0	111
Percutaneous	34	29	36	48	172	71	0
Long-term F/U (mo)	60.1 (48–90)	65.6 (48.5–120.2)	49.6	56 (36–64)	27 (1.5–90)	38.8 (18–78)	59 (2–120)
Incomplete ablation	0%	0%	10.4% (n = 5);	NA	2.9% (n = 7)	4.8% (n = 3)	2.5% (n = 2)
Local recurrence	5.1%	7.5%	8.3%	12% (n = 5); (0% < 4 cm)	3.7% (n = 9)	12.7% (n = 9)	6.3% (n = 5)
Recurrence-free survival	94.2%	92.5	NA	88%	93%	NA	93.3%
Disease-free survival (5 yr)	NA	90.6%	NA	83%	NA	61.9%	NA
Overall survival- 5 yr/10 yr	95.7%	98%	NA	66%	93%	82.3%	72%
	91.1%	93%	NA	NA	Na	60.9%	NA
Cancer-specific survival	100%	100%	NA	NA	99%	96.8%	100%
Metastasis	0%	1.9%	0%	7% (n = 3)	1.2%	6.5%	0%
Probe type	14-G Starburst XL	Cool-tip (90%) Starburst RITA (10%)	Cool-tip	Cool-tip	Starburst XL	Le-Veen	Starburst XL